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## COMMUNICATIONS

### THE EFFECT OF ALUMINIUM AND ITS ALLOYS *ON THE EYE:*

**A Report presented to the Vision Committee of the Medical Research Council**

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#### Introductory

IN 1941 a young British sergeant was hit in both eyes by an exploding rifle grenade. One eye was disorganised and had to be removed. A piece of non-magnetisable metal from the grenade could be seen ophthalmoscopically in the vitreous of the second eye. Enquiry shewed that the metal was in all probability an aluminium zinc alloy. The patient was an intelligent man, desperately anxious for a prognosis. The following investigation arose from a desire to assist him.

*Metallurgical considerations.*—Jessop in 1915 gave details of the composition of the missiles then in common use. He found that bullets were made of lead with a mantle of steel or cupronickel. Shrapnel was composed of fragments of iron, lead, and mixed metal in a metal cylinder usually of iron. The common shell was

made of cast-iron or forged steel with a time-fuse of copper or aluminium. Hand grenades were of cast iron or glass. It will be seen that a high proportion of the missiles were of magnetisable metal.

During the first world war excellent papers were written on the technique of removal of magnetisable fragments by the electro-magnet, but little emerged on the prognosis and surgical treatment of non-magnetisable intra-ocular foreign bodies.

Between the two wars the use for industrial purposes of the aluminium alloys increased greatly. These owed their popularity to their cheapness, and the ease with which they could be adapted to any required purpose. They were light and non-magnetisable. Meanwhile came a marked development of non-magnetisable steels. In consequence the missiles of the recent war have been largely non-magnetisable. Stallard (1944) found that only 38 of 105 intra-ocular foreign bodies from his North African casualties were magnetisable; Savin (1943, also 1945) had an even lower incidence in his service cases—one out of every six, a ratio that obtained both at the beginning and toward the end of the war.

Pure aluminium is used commercially where maximum resistance to corrosion is required, *e.g.*, kitchen utensils and plant used in the chemical and food industries. Because of its good conductivity, the pure metal is also used for electrical conductors. Aluminium alloys contain relatively small amounts of alloying elements, copper, magnesium, manganese, nickel, silicon and zinc being most commonly used, either singly or, more frequently, in various combinations. The addition of alloying elements to aluminium improves its tensile strength and hardness, and aluminium alloys are therefore employed wherever high strength combined with light weight is required, as in aircraft production.

Depending on the manufacturing process for which they are best suited, aluminium alloys can be broadly divided into wrought and cast alloys; the former being produced and used in the form of sheet, strip, extruded sections, forgings, wire, etc., and the latter as castings. Another classification speaks of medium and high-strength alloys. Among the latter, duralumin, an aluminium alloy containing 4 per cent. copper, 0·5 per cent. magnesium and 0·5 per cent. manganese is the best known. In some of its mechanical properties duralumin is equal to mild steel. Another, even stronger alloy recently developed, contains 4—8 per cent. zinc, 4·0 per cent. magnesium and 3·0 per cent. copper as the main alloying elements. Nickel is added to improve the mechanical properties of aluminium alloys at elevated temperatures: thus an aluminium alloy containing 4 per cent. copper, 2 per cent. nickel and 1·5 per cent magnesium (Y-alloy) is used for parts of internal combustion engines, such as pistons.

The more common cast alloys include the aluminium-10-13 per cent. silicon, the aluminium-copper-silicon, and the aluminium-10 per cent. magnesium alloys.

The alloying of aluminium, while it improves the mechanical properties, as a rule reduces the corrosion-resistance of the metal. This reduction in corrosion-resistance is especially marked in alloys containing copper and zinc, whereas the effect of magnesium, manganese and silicon is much less marked.

Since the war the Ministry of Aircraft Production has divided the aluminium alloys into standard groups with recognised variation of composition. The standards of these groups are laid down under specification for aircraft factories and foundries. The group numbers were not in use before the war; and are intended to minimise the mixing of various grades which was customary before that time.

## 1.—Review of the Literature

The literature of intra-ocular foreign bodies of aluminium is fragmentary and scattered.

The first references to such foreign bodies date to World War I (1914-18). In the 1913 edition of his monumental study of the injuries of the eye Wagenmann makes no reference to the subject; and the edition of 1926 dismisses the matter in a sentence: "During the world war intra-ocular foreign bodies of aluminium were frequently observed; they were generally minimal splinters; aluminium is relatively well tolerated, the inflammatory reaction being mild."

Handmann in 1915 and Pichler in 1918 drew attention to the appearance suggestive of synchisis scintillans following the entry of small foreign bodies into the vitreous. They recorded these foreign bodies as consisting of lead. Hertel in his review of ocular experiences during the 1914-18 war refers to these observations and states that he regarded such foreign bodies as consisting of aluminium, for unlike lead, they were not radio-opaque. A similar suggestion was made by Weigelin in 1917 in a study of non-ferrous intra-ocular foreign bodies; he regarded some ophthalmoscopically visible foreign bodies with a lustrous metallic sheen as "probably of aluminium," especially when they were negative to the sideroscope.

Whatever may have been the validity at the time of this distinction modern radiological technique has robbed it of value.

The first clearly recognised case of an intra-ocular foreign body of aluminium was noted by Jess in 1924. Some workers on an underground construction lost a blasting cartridge made of pure aluminium without the addition of lead. It exploded on being

picked up in the street by a man aged 40 years. He sustained injuries to the left eye. There was a perforating wound 1-2 mm. long in the centre of the cornea, and a grey-white foreign body was embedded in the iris down and out with the point free in the anterior chamber. The corneal wound shewed numerous fine metallic dots giving the wound of entry the appearance of a silvery track. Fine silvery dots were also seen on Descemet's membrane near the wound and over most of the iris, especially towards the limbus. The foreign body did not respond to the sideroscope nor to the giant magnet, and X-ray did not shew any definite shadow. No attempt was made to remove the fragments, "owing to the repeatedly noted tolerance of the inner eye to aluminium." The eye rapidly settled down; and during the course of two years over which it was observed, the only changes seen were depigmentation of the pupillary margin near the foreign body, and some pigment deposition at the root of the iris. A faint lens opacity noted at the time of the accident did not increase in intensity.

In reporting his case Jess stresses that in his patient it was clearly known that the foreign body was of aluminium, while previous records had assumed foreign bodies were of aluminium on inconclusive evidence, or had dealt with non-magnetic intraocular foreign bodies in general.

The second case was reported by Fricke in 1925. A shooting instructor, aged 47 years, sustained injuries to both eyes from an exploding detonator, the casing of which consisted of aluminium. In the right eye there was a small perforating corneal wound. The surrounding corneal tissue, Descemet's membrane, the iris, and the anterior capsule all shewed numerous fragments of glistening silver-like metallic dust. Opposite the corneal wound, but considerably larger than it, there was a hole in the iris. The lens, vitreous and fundus were normal. There was no inflammatory reaction and recovery was good. The left eye suffered more severely. There was a large perforating wound at the limbus with prolapse of iris, turbidity of the aqueous, keratic precipitates, and restriction of visual field upwards. There was also fine metallic dust, distributed as in the right eye. The lens was opaque. Fricke holds that the aluminium did not affect the course of the recovery. The iridocyclitis of the left eye cleared up under treatment, and he ascribes the repeated recurrences as probably due to the associated apical phthisis from which the patient suffered.

Hesky in 1933 also described a case of aluminium in the anterior chamber. A mechanic, aged 42 years, came with a history that some five years previously he had been hit in the eye by a frag-

ment of pure aluminium. There was acute pain in the eye, and some blurring of vision. An X-ray as well as an attempted magnet extraction were apparently negative. The eye quieted down quickly and remained quiet for three years, when it suddenly became violently inflamed with deterioration of vision. Hesky noted circumcorneal injection and a corneal opacity covering a foreign body in the anterior chamber, the foreign body being visible through clear cornea when the patient was made to look sideways. X-ray examination had not revealed it. Operative removal of the fragment led to the clearing of the corneal opacity; and the lens, vitreous, and fundus were found normal. Examination confirmed that the splinter removed from the anterior chamber was indeed aluminium.

In addition to these clinical observations the following experimental records have to be noted:—

1. Jess in stressing the innocuousness of aluminium in his case reports mentions that he satisfied himelf on this point by animal experiments. No further details are given.

2. Fontana (1938) reports three series of observations, each carried out on four rabbits:—

(*a*) Implantation of splinters of aluminium in the anterior chamber. There were no inflammatory reactions. The eyes were enucleated after 55-85 days. Histologically the only change observed was some thickening of the corneal epithelium at the site of the incision scar.

(*b*) Implantation of filings of aluminium into the anterior chamber. There were mild inflammatory reactions in the anterior segment of the eyes. The eyes were removed after 10 days. Histologically numerous particles of aluminium and some lymphocytes were seen in the corneal parenchyma and there was some atrophy of the ciliary body. The lens was clear.

(*c*) Implantation of splinters of aluminium in the vitreous. There was no reaction and the eyes were enucleated after 30-64 days. Histologically there was mild lymphocytosis at isolated areas in the cornea and ciliary body.

In contrast to these relatively negative findings, Fontana reports three parallel observations on bronze. In each case severe destructive processes occurred.

3. Mielke (1941) briefly refers to animal experiments conducted over a period of two years. Pure aluminium and various aluminium alloys were implanted at ophthalmoscopically visible sites in the animal eye. Pure aluminium itself and some alloys were inert, whilst some other alloys liberated after a short while

flakes and corpuscles of metallic appearance. These could be seen floating freely in the vitreous. Mielke stresses that the inert behaviour of aluminium was unexpected in view of the purulent reaction aluminium splinters produce in the skin. As a practical corollary he advises against the " dangerous procedures " aiming at the operative removal of aluminium splinters from the interior of the eye. (The author refers to a fuller account of his findings in the Ber. f. deut. ophthal. Gesellsch. for 1940. This publication does not appear to be available at the present.)

In discussing the mild reaction of the eye to aluminium Jess held that this was to be explained by the " porous " nature of the metal. He believed that after penetrating the cornea an aluminium splinter broke down into powder. Fricke found this suggestion improbable in view of the hardness of aluminium. He would on the contrary expect a splinter of aluminium to retain its shape even if it were made semi-liquid by the heat of an explosion. In support of his views he adduces arguments bearing on the melting point and specific heat of aluminium in contrast to those of copper and iron.

A careful reading of the three clinical cases reported in detail hardly substantiates the view often expressed that aluminium is innocuous to the eye. In Fricke's patient there were recurrent attacks of cyclitis and Hesky's patient showed distinct if delayed intolerance to the aluminium fragment. There do not appear to be any cases recorded in detail on the effect of aluminium in the eye at a deeper level than the anterior chamber and there is therefore no actual knowledge of the effect of aluminium on the lens, vitreous or fundus.

Jess' and Mielke's experimental work is not reported in sufficient detail to allow adequate discussion. Fontana's experimental work with aluminum is given rather as a contrast to the violence of reaction of bronze, than as a considered study of the effects of aluminium. The experiments would have been more conclusive had the metal been left for longer periods in the eyes before enucleation. Even so, aluminium was not found by him to be completely inert.

The available data in the literature therefore suggests that an intra-ocular aluminium foreign body does not produce the destructive changes seen with iron and copper; but there is no reason to believe that the metal is completely innocuous to the eye. The stress hitherto laid on the inertness of aluminium by many writers seems to be made in a comparative sense to the severity of action of the heavy metals, rather than as an absolute statement based on a separate consideration of the effects of aluminium.

## 2.—Clinical Case Reports on Eyes with Intra-ocular Fragments of the Aluminium Alloys

The fluctuating circumstances of the war rarely allowed observation of patients for long periods. When the first war casualties began to arrive it was soon found that a high proportion of eyes were injured by fragments of aluminium alloy. Among the Dunkirk wounded several cases were seen where such fragments were embedded in the eye. One Algerian soldier had many small fragments of white metal dotted about in the vitreous. Afterwards other such cases were seen; but only two were watched long enough to provide adequate information as to prognosis.

CASE 1. On December 4, 1941, a young sergeant-instructor was injured by the premature explosion of a rifle grenade, made of "aluminium-zinc alloy."* He had been hit in both eyes. The left globe was disorganised and there were severe lacerations of both lids. There was a puncture wound of the right eye and a small piece of white metal could be seen in the vitreous. Several teeth were broken. His right tympanic membrane was ruptured. He had multiple puncture wounds of the right arm, chest, side of neck, and lips. There were injuries to the right musculocutaneous, musculospiral, and circumflex nerves. The left eye was removed on December 8, 1941. The right eye was carefully watched over a long period.

At first the piece of metal presented a bright and silvery appearance as it lay on the retina overlying the inferior temporal branch of the arteria centralis retinae about 6 disc-diameters from the papilla. Gradually the metal assumed a powdery white coating, and it could be seen that the retina in its neighbourhood was turning greyish in colour. Later on the metal was found to have shifted slightly leaving a mark or imprint on the retina to shew its original position. (Fig. 1.) On the most peripheral corner of the imprint there was a white incrustation which seemed to have separated from the white encrusted piece of metal, for the loose fragment now shewed a silvery exposed surface at one side. Later the fragment settled on the retina about two disc-diameters distant from its original position. Here it stayed for some months.

Later still the fragment shifted about 1½ disc-diameters from its second seat of lodgment, and in its third resting place it finally disintegrated into a mass of powdery white débris. On January 6, 1944, the two retinal imprints could be plainly seen. (Fig. 2.) There was some retinal pigmentation in the neighbourhood of

* This was the description of the metal given by official sources. Mr. Freeman Horn, of the British Aluminium Company, Ltd., holds that the early corrosion and breaking up of the metal in this case would suggest that the fragment was a zinc-base aluminium alloy such as was commonly used for rifle grenades.

the white mass of débris near the second imprint. Since that date the appearances have remained unchanged. Meanwhile the patient has been boarded out from the service. The corrected vision in the eye is 6/5. He is earning his living as a clerk.

It can be judged that this particular fragment was not completely inert, as it disintegrated slowly and appeared to cause local patches of necrosis in the adjacent retina. There has been no evidence of any remote chemical action.

CASE 2. This patient was struck by a piece of German shell-casing, and there is only strong presumptive evidence that the missile was in fact a piece of aluminium alloy. His Bren gun carrier was hit by a German 88 mm. shell on September 28, 1943, in Italy. He sustained burns on his back and left arm, and multiple puncture wounds of face, neck and arms. Both eyes were hit by shell fragments. Attempts to save the left eye failed. It was enucleated in North Africa on November 1, 1943, when it was found to contain several non-magnetisable metallic fragments.

He was admitted to Horton Hospital on December 10, 1943. The right eye was emmetropic with vision 6/18. The right cornea shewed a faint nebula with scattered patches of pigment thought to be of iritic origin on the posterior surface. There were patches of iris pigment on the anterior lens capsule. The lens itself seemed clear, as was the anterior chamber of the eye. There were many vitreous opacities, and two small pieces of metal were seen suspended in the anterior vitreous. These fragments were covered with a white coating and were very similar to the small oxide coated aluminium fragments which will be described later in the account of the rabbit experiments.

A large metallic fragment lay on the peripheral retina. Near it was an oval mark on the retina which was thought to be a local imprint as described in Case 1.

The patient was kept under observation for 7 months. During this period the vision dropped to 6/24. Vitreous opacities increased. The large metallic fragment gradually acquired a white coating, and the retina in the adjacent region gradually began to shew a diffuse pigmentation. For instance on January 5, 1944, the large fragment was clearly seen covered with a grey incrustation and surrounded by streaky retinal pigment which was also visible in streaks, dots, and lumpy aggregations in the adjacent retina. (Fig. 3.) The pigment appeared to be retinal rather than choroidal and was thought to indicate death of rods and cones in the pigmented areas. The " imprint " near the metal seemed to involve deeper structures: large choroidal

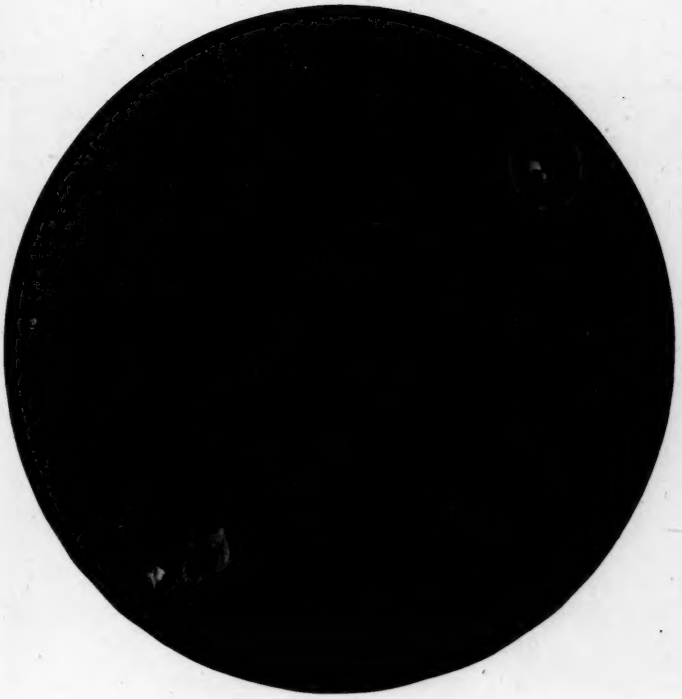

FIG. 1.

Sergeant W.J.H. Right fundus 11 months after entry of foreign body. The metallic fragment can be seen down and outwards, and the "imprint" indicating its previous site just above it.

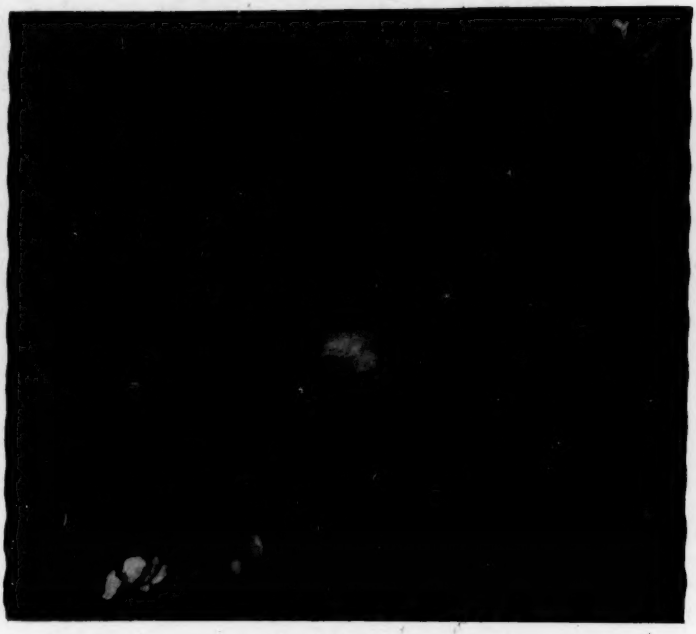

FIG. 2.

*The same eye* 25 months after the injury. The foreign body has shifted farther down, and two "imprints" are now seen. *The fragment itself* is breaking up. A mass of powdery white débris is present.

vessels could be seen traversing the patch. In the foreground could be seen a minute fragment of white-coated metal suspended in the vitreous.

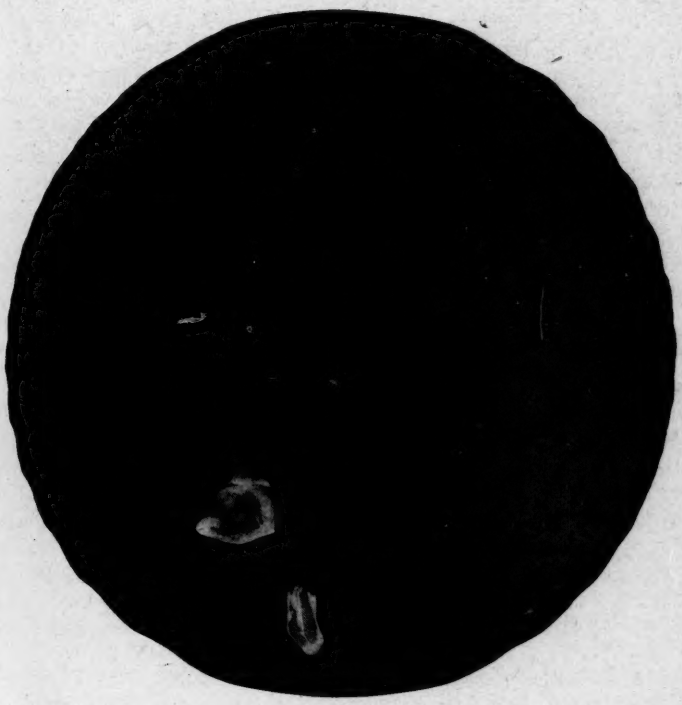

FIG. 3.

*Private R.N. Fundus appearance 16 months after injury. A large fragment is seen with a grey incrustation, and is surrounded by streaky retinal pigment in the adjacent retina. Below the fragment an "imprint" can be seen exposing the underlying choroidal vessels.*

The patient has latterly been much troubled by swirling clouds of vitreous opacities. As there is still unabsorbed metal present in the eye, further deterioration in vision is likely. There seems no prospect of extracting the metal from this eye, the magnet having been tried unsuccessfully.

In this case besides local chemical reaction to the metal, there has been some more diffuse reaction, as shewn by the pigmentary changes on cornea, lens capsule, and in retina, and by the increasing vitreous opacities. It is unfortunate that no metallic fragments have been submitted to analysis.

### 3.—Experimental Observations on Rabbits

In preliminary experiments the animals were picked without any special regard to their fur colour. Presently it was realised that the pigmentation of a rabbit's fundus bears considerable relationship to its colour. In judgments of whether a fundus condition was pathological it was necessary to start with a standard type of fundus, excluding partial choroidal colobomata which were encountered unduly frequently in the rabbits available. Eventually a suitable standard rabbit type was selected from a silver-grey chinchilla-rex cross. This gave a light coloured fundus with minimal peripheral pigmentation. This was the type employed for the experiments with pure aluminium.

Only one animal of the series suffered from intercurrent disease; it was eliminated.

#### 1.—STANDARDISATION OF TECHNIQUE

Standardisation was secured by the following measures:—

(*a*) *Anaesthesia.*—It was necessary to evolve a technique which would allow the implantation of metallic fragments in the rabbit's eyes without undue risk of death, without movement of the eyes under anaesthesia, and without post-anaesthetic complications. The eyes of the first three rabbits used were anaesthetised by instillations of 5 per cent. cocaine drops. In the first case it was thought that aqueous was lost rather rapidly from slight movements made by the animal. In the second case anaesthesia was satisfactory. The third animal started violently when the operation on its second eye was in progress causing a prolapse of iris and vitreous.

Subsequently general anaesthesia with a solution of nembutal gr. 1 to the c.c. given intravenously into the marginal vein of the ear was tried. About 0·75 c.c. was found necessary for a moderately large rabbit. At first smaller doses were used in conjunction with local cocaine anaesthesia. If the animal was too lightly anaesthetised, sneezing or reflex squealing sometimes occurred. Better results were obtained when slightly larger doses of nembutal were employed without cocaine locally. This ran rather near the danger-line. Two rabbits died almost immediately after receiving their injections apparently from sudden cardiac failure. A third rabbit seemed to recover satisfactorily and hopped round its cage. A few hours later it was found dead from no apparent cause. As it had been a healthy animal, the presumption was that death was due to some after-effect of the anaesthetic. Generally rabbits anaesthetised with nembutal recovered rapidly without any apparent after-effects from the drug. The possibility that the effects noted in the experiments might be changes caused

by a near-lethal dose of nembutal could be clearly eliminated, for such effects were observed in eyes which had been anaesthetised exclusively with cocaine, and were not observed in the unoperated eye of nembutal-anaesthetised animals which had aluminium or its alloys implanted in one eye only.

(*b*) *Technique for Anterior Chamber and Vitreous Implantations*.—To make the experiments strictly comparable a standardised operative technique had to be evolved. In proportion to the size of the globe the extra-ocular muscles in the rabbit are much thinner and flatter than in man. The nictitating membrane also has its muscles, and must be considered in planning operative procedures. Need of postoperative treatment or of dressings obviously had to be avoided. In the case of a vitreous implantation it was desirable to insert the metal so as to be easily visible ophthalmoscopically. The methods evolved proved their soundness in 26 successful implantations into the anterior chamber and 9 into the vitreous.

1. *Anterior chamber*.—Under anaesthesia as already described an incision 3 mm. long and 2 mm. distant from the limbus was made with a Taylor knife in the postero-superior corneal quadrant. The incision passed obliquely through the corneal stroma into the anterior chamber; and it was often possible to remove the knife without losing aqueous. The metallic fragment, sterilised by boiling in distilled water, was picked up by toothless curved iris forceps and inserted into the anterior chamber. An iris repositor was gently inserted to slide the fragment well into the anterior chamber. This manipulation sometimes had to be repeated several times where several fragments were inserted. Care was taken to select fragments of smooth surface to avoid unintended trauma.

This operation gave good results in general; but had the weak point that at the end there was little aqueous in the anterior chamber, and as the anterior chamber reformed the iris tended to adhere to the inner aperture of the corneal wound. An anterior synechia, usually only of thread-like consistency, occurred in 19 of the 31 operations. Filling the anterior chamber with saline might have lessened the incidence of synechiae, but was thought undesirable as introducing complicating factors, and rendering the technique less simple. In order to estimate the part played by operative trauma in the results, two eyes (rabbits 20 and 24) had the operation performed without the insertion of any fragment. Instruments were passed through the wound as in a standard implantation. Five days after the operation the wound in rabbit 20 had healed. There was a thread-like anterior synechia and a dot-like opacity in the lens at that site. This opacity was capsular and grew less marked

as time went on. In rabbit 24 there was also a small anterior synechia; but the eye quieted quickly and lens and media remained clear. In rabbit 19 an inert piece of metal (3 cms. of coiled-up platinum wire weight 15 mg.) was inserted into the anterior chamber by the usual technique. The entry wound healed quite uneventfully and without anterior synechiae.

2. *Vitreous chamber.*—Here the problem was to insert the metal through a puncture well protected from infection, and sufficiently far back to render the inserted fragment easily visible ophthalmoscopically; moreover vorticose veins and other large vessels had to be avoided. A Graefe knife puncture was made behind the equator slightly posterior to the vertical meridian (*i.e.*, 10 o'clock for the right eye, 2 o'clock for the left eye); the blade was entered in a meridianal direction, as delicately as possible, and not very deeply into the vitreous. In some instances there was a little bleeding, but less than would have been found after the equivalent operation on a human eye. Curved iris forceps proved the best instrument for the insertion of metallic fragments. It was rather common at first for the fragments to adhere to the forceps on withdrawal, this could be obviated by a slow withdrawal of the forceps.

There seemed few complications from this operation. Contrary to expectation no cases of detached retina occurred in the series. In rabbit 24 a control vitreous puncture was performed on one eye. The puncture healed rapidly and uneventfully.

No complications which might be construed as anything corresponding to sympathetic ophthalmitis in man nor any signs of infection were seen in the series.

Taking the experiments as a whole it was clear that operative trauma played a small, if any, part in the effects produced by the metallic fragments. It has been suggested that since the maximum life of a rabbit was approximately one-tenth that of a man, pathological processes might be correspondingly speeded up; no such acceleration was noted in these experiments.

## 2.—Analysis of Experimental Findings

(*a*) *Changes in the metallic fragments.*—Most experiments were performed with 99·9 per cent. pure aluminium, which was employed in 16 eyes; in 2 eyes slightly less pure aluminium (98 per cent.) was employed. For purposes of comparison aluminium copper (group 2) was used in 4 eyes, aluminium magnesium (group 3) in 2, aluminium nickel copper (group 4) in 4, aluminium copper (group 6) in 2, aluminium silicon (group 8) in 2, and aluminium zinc (group 9) in 2 eyes. In one further case a piece of platinum wire was employed.

The only case where the metal was unaffected was that of the platinum. The 18 eyes tested with pure aluminium formed a homogeneous group. The various aluminium alloys were each tested in a few cases to see if there was much qualitative difference in their effect. It proved impossible to discriminate by the available clinical means between the behaviour of fragments of pure aluminium and fragments of alloy.

None of the aluminium or alloy fragments remained unaltered. Within a few days or weeks of insertion most fragments became coated with a thin film of powdery white material (9 instances). In some cases the film presented the appearance of a white or yellowish-white exudate and was thicker than the usual white coating (9 instances). In other cases there was a fibrinous coating to the metal (6 instances). This was confirmed in rabbit No. 3 which was killed 3 days after an anterior chamber insertion of aluminium copper (Group 2). The fragment was withdrawn in its coat from the anterior chamber and the coating of the fragment was investigated microscopically. A change, which on the whole developed rather later (10 instances) was the appearance of gelatinous material around the fragments—a development which sometimes ran parallel to absorption of the metal. A late effect observed in 11 instances was fragmentation or powdering of the metal; it was never seen before the sixth week. Some of the powdered metal was often observed in positions far from the original situation of the fragment. This may possibly have been connected with the lively movements and skittish behaviour of the younger rabbits. Sometimes these movements shifted the main fragments from one position to another inside the eye. Substantial or complete absorption of the metal occurred as a comparatively late change in 6 cases. The surface of such metal tended to assume a honeycomb appearance. Iridescence was sometimes observed to appear near a sharp edge or corner of metal, presumably indicating some chemical change. Table I shows the time sequence of these changes.

*Changes in the fragments in relation to Dosage of Metal.*—Doses employed ranged between 0·3 mg. to 20 mg. In the larger doses multiple fragments were usually employed. A dose of 0·3 mg. was employed in 8 instances, 0·4 mg. in 4, and 0·5 in 7. Doses of 0·9 mg., 4 mg., and 6 mg., were employed in 2 instances each, whilst doses of 1·5 mg., 3·32 mg., 4·98 mg., 6·64 mg., 8·0 mg., 8·3 mg., 10·0 mg., 12·0 mg., and 20·0 mg. were employed in single instances.

No alteration in the qualitative changes observed in the fragments appeared to occur when larger doses or multiple fragments were used. An odd feature was that when several fragments

TABLE I. *Approximate Time of Onset of Changes in Metal.*

(Pure aluminium O. Aluminium alloy X.)

| Weeks | Coated white | Covered exudate | Fibrin | Jelly | Powdered | Absorbed |
|---|---|---|---|---|---|---|
| 1 | O | OOXX | O | - | - | - |
| 2 | X | - | XX | - | - | - |
| 3 | - | - | - | - | - | - |
| 4 | - | - | O | O | - | - |
| 5 | - | O | - | O | - | - |
| 6 | O | O | - | - | O | - |
| 7 | OX | X | - | X | OXX | - |
| 8 | X | X | - | - | X | OX |
| 9 | X | - | - | - | O | - |
| 10 | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - |
| 12 | OX | O | - | - | XX | - |
| 13 | - | - | - | XX | - | - |
| 14 | - | - | XO | X | X | - |
| 15 | - | - | - | - | - | - |
| 16 | - | - | - | OO | O | O |
| 17 | - | - | - | - | - | - |
| 18 | - | - | - | - | - | - |
| 19 | - | - | - | - | - | - |
| 20 | - | - | - | - | - | OO |
| 21 | - | - | - | - | - | - |
| 22 | - | - | - | - | - | - |
| 23 | - | - | - | - | - | - |
| 24 | - | - | - | - | - | - |
| 25 | - | - | - | - | - | - |
| 26 | - | - | - | - | - | - |
| 27 | - | - | - | - | - | - |
| 28 | - | - | - | X | - | - |
| 29 | - | - | - | - | - | - |
| 30 | - | - | - | - | - | - |
| 31 | - | - | - | - | - | - |
| 32 | - | - | - | - | - | - |
| 33 | - | - | - | - | - | - |
| 34 | - | - | - | - | - | - |
| 35 | - | - | - | - | - | - |
| 36 | - | - | - | - | - | - |
| 37 | - | - | - | O | - | - |
| 38 | - | - | - | - | - | - |
| 39 | - | - | - | - | - | - |
| 40 | - | - | - | - | O | - |
| 41 | - | - | - | - | - | - |
| 42 | - | - | - | - | - | - |
| 43 | - | - | - | - | - | - |
| 44 | - | - | - | - | - | - |
| 45 | - | - | - | - | - | - |
| 46 | - | - | - | - | - | - |
| 47 | - | - | - | - | - | - |
| 48 | - | - | - | - | - | X |

were employed in the same eye, while the alterations were similar in type, the various fragments shewed enormous variations in the degree they were affected. For instance one piece might be bright and shiny, while a second might be covered with a white powdery coat, or coated with gelatinous material. These differences did not seem to correspond to any constant factors. When multiple pieces were employed, they were cut from the same sheet of metal with the same stainless steel knife, and sterilised by boiling in the same test-tube. An impression was gained that changes were more rapid where two pieces of metal were in contact and at those edges of the metal which lay in actual contact with iris, lens, or cornea. As the multiple fragments were generally of the same shape, it was not thought that surface area was the factor involved; perhaps small differences in electrical potential play some part in these variations.

(*b*) *Local effects of fragments on adjacent ocular structures.* (Table II.) Fragments of aluminium or alloy which came into apposition with the internal ocular structures were frequently found to form a greyish necrotic patch in the subjacent structure. This "imprint" took the shape of the fragment, but varied slightly according to the situation in the eye. Sometimes in the iris and lens there was a tendency for the metallic fragment to sink into the soft tissues. In some cases the imprint became vascularised or occasionally pigmented. The incidence of imprints and their distribution are indicated in the last column of Table II.

*Corneal imprints* were noted in six eyes. In one case (rabbit 22, R. eye) the end of a fragment impinged on the posterior corneal surface. Three weeks later there was a diffuse haze in the cornea in this region and the end of the piece of metal was coated with jelly. Later the metal absorbed leaving a grey patch on the posterior corneal surface. Slit-lamp examination shewed metallic powder adhering to the patch. In a second case (rabbit 16, R. eye) a diffuse imprint formed round a piece of metal which gradually eroded forward into the corneal stroma. A third imprint (rabbit 16, L. eye) shewed as a pigmented plaque on the posterior corneal surface. A fourth imprint (rabbit 14, R. eye) shewed as an irregular diffuse patch containing a fragment of metal. A fifth imprint (rabbit 14, L. eye) was irregular in shape, and appeared to shew hyaline corneal degeneration. The sixth fragment (rabbit 2, R. eye) was observed at first coated with white and adherent to the posterior corneal surface. Eventually a vascularised scar formed containing metallic fragments.

*Iris imprints* were observed in 12 eyes. In one case (rabbit 4, L. eye) a grey patch was first noted when the piece of metal

TABLE II.—*Ocular changes following Intra-ocular Implantation of Aluminium and Aluminium Alloys. Aluminium.**

Anterior Chamber Implants

| No. | Mg. Dose | Days Period | Cornea | | | Iris changes | | | Lens changes | | | Fundus changes | | | Imprint | | | | Eye disorganised |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nil. | Slight | Gross | Nil. | Slight | Gross | Nil. | Slight | Gross | Nil. | Slight | Gross | Cornea | Iris | Lens | Fundus | |
| 2L | 0·3 | 118 | – | x | – | – | x | – | – | x | – | – | x | – | – | – | – | – | – |
| 5R | 0·5 | 207 | – | x | – | – | x | – | – | – | x | – | – | x | – | x | – | – | – |
| 5L | 0·5 | 207 | – | x | – | – | x | – | – | – | x | – | x | – | – | x | – | – | – |
| 2R | 1·5 | 118 | – | x | – | x | – | – | – | x | – | – | x | – | – | – | – | – | – |
| 13R | 4·0 | 348 | – | – | x | – | – | x | – | x | – | – | x | – | – | x | – | – | – |
| 13L | 4·0 | 348 | – | – | x | – | – | x | – | x | – | – | – | x | – | x | – | – | x |
| 14R | 6·0 | 348 | – | – | x | – | – | x | – | x | – | – | x | – | x | x | – | – | – |
| 14L | 6·0 | 348 | – | x | – | – | x | – | – | x | – | – | x | – | x | x | – | – | – |
| 16L | 8·0 | 342 | – | – | x | – | – | x | – | x | – | – | x | – | x | – | – | – | – |
| 16R | 10·0 | 342 | – | – | x | – | – | x | – | x | – | – | x | – | x | x | – | – | x |
| 22R | 12·0 | 238 | – | x | – | – | – | x | x | – | – | x | – | – | x | x | – | – | – |

Vitreous Implants

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8R | 0·9 | 336 | x | – | – | – | x | – | – | x | – | – | – | x | – | – | – | x | – |
| 8L | 0·9 | 336 | x | – | – | – | x | – | – | x | – | – | – | x | – | – | – | x | – |
| 17R | 3·32 | 334 | – | – | x | – | – | x | – | – | x | – | x | – | – | – | – | – | x |
| 17L | 4·98 | 334 | – | x | – | – | – | x | – | – | x | – | x | – | – | – | – | – | – |
| 18L | 6·64 | 334 | – | | – | – | – | x | – | – | – | – | x | – | – | – | – | x | – |
| 18R | 8·3 | 334 | – | x | – | – | – | x | – | x | – | – | x | – | – | – | – | x | – |
| 23R | 20·0 | 237 | – | – | x | – | – | x | – | – | x | – | – | x | – | – | – | – | x |

* The aluminium was 99·9% pure in all cases, except No. 2 in which metal, 98% pure, was used. x = reaction present.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18R | 8·5 | 334 | – | x | – | – | – | x | – | x | – | – | x | – | – | x | – | – | – | – |
| 23R | 20·0 | 237 | – | – | x | – | – | x | – | – | x | – | – | x | – | – | – | – | x | |

* The aluminium was 99·9% pure in all cases, except No. 2 in which metal, 98% pure, was used. x = reaction present.



*Aluminium Alloys*

Anterior Chamber Implants

| No. | Type of Alloy Group No. | Mg. Dose | Days Period | Cornea | | | Iris changes | | | Lens changes | | | Fundus changes | | | Imprints | | | | Eye disorganised |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Nil. | Slight | Gross | Nil. | Slight | Gross | Nil | Slight | Gross | Nil. | Slight | Gross | Cornea | Iris | Lens | Fundus | |
| 3R | 2 | 0·3 | 3 | x | – | – | x | – | – | – | x | – | x | – | – | – | – | – | – | – |
| 3L | 2 | 0·3 | 3 | x | – | – | – | – | x | x | – | – | x | – | – | – | – | – | – | – |
| 10R | 4 | 0·3 | 323 | – | x | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 10L | 4 | 0·3 | 323 | – | x | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 1R | 6 | 0·3 | 235 | – | – | x | – | x | – | – | x | – | – | x | – | – | – | x | – | – |
| 1L | 6 | 0·4 | 235 | – | – | x | – | x | – | – | x | – | – | x | – | – | – | – | – | – |
| 7R | 8 | 0·4 | 336 | – | x | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 7L | 8 | 0·4 | 336 | x | – | – | – | x | – | – | x | – | – | – | x | – | x | – | – | – |
| 4R | 9 | 0·4 | 215 | – | x | – | – | x | – | x | – | – | – | x | – | – | – | – | – | – |
| 12R | 2 | 0·5 | 231 | x | – | – | – | x | – | – | x | – | – | x | – | x | x | x | – | – |
| 12L | 2 | 0·5 | 231 | x | – | – | – | x | – | – | x | – | – | x | – | – | x | – | – | – |
| 11R | 3 | 0·5 | 317 | – | x | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 11L | 3 | 0·5 | 317 | – | x | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 4L | 9 | 0·5 | 215 | – | x | – | – | x | – | x | – | – | – | x | – | – | x | – | – | – |

Vitreous Implants

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9R | 4 | 0·3 | 322 | x | – | – | – | x | – | – | x | – | – | – | x | – | – | – | – | – |
| 9L | 4 | 0·3 | 322 | x | – | – | – | – | x | – | – | x | – | – | x | – | – | – | – | x |

shifted. Later the imprint was vascularised. The piece of metal in its new position sank slowly into the iris. In a second case (rabbit 5, L. eye) a white mass was first noted at the site of a partially absorbed piece of metal. A white iris imprint resulted. A similar white imprint was seen in a third eye (rabbit 5, R. eye). In a fourth case (rabbit 7, L. eye) the metallic fragment lay for some time on the iris surrounded with jelly. After the metal had become absorbed there was a grey iris imprint. In a fifth eye (rabbit 12, R. eye) a necrotic patch was noted on the iris after the metal shifted. In a sixth eye (rabbit 12, L. eye) there was a large grey imprint noted after shifting of the metal. A large area of iris atrophy resulted with new vessel formation in the adjacent iris. In a seventh eye (rabbit 14, R. eye) there were multiple grey iris imprints powdered with metal. In an eighth eye (rabbit 14, L. eye) a grey iris imprint gradually became depigmented and atrophic. A similar sequence of events occurred in a ninth eye (rabbit 13, R. eye). Three other eyes shewed grey iris imprints (rabbit 13, L. eye; 16, R. eye; 22, R. eye). Altogether vascularisation of an imprint was noted in 3 instances in the iris.

*Lens imprints.* The lens differed from other portions of the eye in being more susceptible to diffuse changes than to localised alterations. Lens opacities occurred in 28 instances; but these could be classified as " imprints " in 2 instances only. In the first (rabbit 1, R. eye) the lens capsule became opaque where a metallic fragment rested. Later a deeper opaque " imprint " formed in the lens. In the second case (rabbit 12, R. eye) a square fragment lay on the anterior lens capsule. The fragment shifted shewing a necrotic grey patch. In some instances pieces of metal resting on the surface sunk gradually into the substance of the lens.

*Fundus imprints* were noted in four instances. In the first (rabbit 8, R. eye) fundus examination shewed a metallic fragment far forward with an iridescent white coat. Behind it lay a pigmented scar thought to be a retinal imprint. Later the metal shifted. The scar was now seen to be dead-white with pigmented edges. In the new site of the metal the adjacent retina shewed pigmentation. In the second eye (rabbit 8, L. eye) a pigmented patch thought to be an imprint lay posterior to the metal. In the third eye (rabbit 18, R. eye) at one stage the metallic pieces were coated with a white film. Postero-superiorly was a white imprint, partially vascularised. In the fourth eye (rabbit 18, L. eye) near the lower end of a strip of metal a strand of gelatinous material extended from metal to retina. Powdery metal could be seen in the strand. Near this point were two white and necrotic imprint

areas. Later one of these patches shewed deep vessels (apparently choroidal) running across it, and pigmentation around it.

(c) *General Effects on the Eye.*—The general effect of the introduction of aluminium and alloy fragments into the eye, as opposed to the local effects already discussed, can be dismissed briefly. In view of the mobility of many of the fragments, a distinction between local and general effect cannot be maintained too rigidly, but it is convenient for descriptive purposes. An analysis of the effects noted is given in Table VI.

The lens was one of the structures most commonly affected indirectly. Lens opacities were noted in 28 instances. The opacities varied in type, often in the same lens. Simple striae were noted in 13 instances; dots and vacuoles in 10, and irregular opacities in 10 instances. The opacities were mainly in the anterior capsule in 5 instances. In 6 cases the opacities were in the anterior cortex, and in 4 cases in the posterior cortex of the lens. In 4 cases polychromatic lustre was noted under the slit-lamp. As already noted there were two lens "imprints." In several cases fragments of metal sank into the substance of the lens. Oddities included two opacities in the form of a small ring. There were three complete cataracts of chalky white type.

None of the normal rabbits examined shewed any lens opacities. There seemed no doubt that the large number of opacities described were toxic in origin, either directly from immediate contact, or indirectly from disturbances in the nutrition of the lens arising from the action of the fragments on the uveal tract.

Inflammatory changes in the uveal tract were noted in a number of instances. These changes were usually gradual. Anything approaching the picture of an acute iridocyclitis with keratic precipitates as seen in man was noted in only two eyes. Posterior synechiae appeared in 10 instances, causing iris bombé in 2 eyes. Iris atrophy on transillumination was noted as a late change in 14 eyes. In one case the eye became shrunk and fibrosed.

Vitreous opacities were noted in 5 cases, blood in the vitreous in one.

The assessment of fundus appearances in the rabbits proved difficult, except in the case of gross changes such as the localised "imprints" already described in the neighbourhood of metallic fragments. A series of normal rabbits when carefully examined ophthalmoscopically shewed wide variations in the distribution and extent of their fundus pigmentation. The picture was complicated by some of the animals having pigmentation on the lower part of the fundus possibly connected with a tendency

to choroidal coloboma possessed by some of the strain. As already noted the degree of pigmentation bore some relation to the colour of the rabbits, and silver grey rabbits of special rex-chinchilla cross gave some approach to fundus standardisation. This standardisation was, however, approximate, as normal rabbits acquire more fundus pigmentation with increasing age. Of the 48 eyes experimented upon, 42 shewed initial patchy fundus pigmentation. In the course of experimentation 23 eyes developed pigmentation of what was thought a pathological degree, though this judgment was arbitrary. Six eyes developed obvious localised patches of choroiditis. Retinitis proliferans developed in three instances.

It must be concluded that toxic fundus changes were not uncommon, a finding confirmed by histological evidence.

A general reaction frequently observed was the formation of new vessels in the eye. For instance the corneal operation scar shewed superficial vascularisation in 15 instances; but in this situation the vessels could not be dissociated from direct operative trauma. In other parts of the eye this discrimination could be made. The cornea shewed superficial vessels in 10 instances. There was interstitial vascularisation in 2 eyes, deep vascularisation in two. New vessels formed at the limbus in 3 instances. Iris imprints became vascularised in 3 instances. In 2 eyes large vessels appeared on the lens capsule. Vessels appeared around metallic fragments in 3 cases. One fundus imprint became vascularised. New vessels appeared in the 3 cases of retinitis proliferans encountered.

Insufficient control experiments were performed to settle the question whether this common neo-vascularisation was in any way specific for aluminium or aluminium alloys.

A large number of isolated oddities were noted among the eyes used for experimentation. Two eyes developed bullous keratitis. One eye became buphthalmic (or staphylomatous) attaining a corneal diameter of 19 mm. There were two cases of zonular keratitis, one of interstitial, and one of deep keratitis. In one case cholesterol crystals appeared in the corneal stroma. Folds in Descemet's membrane were twice observed. In two cases pigment appeared on the corneal surface, once at the limbus.

(*d*) *Size and site of fragment.*—In the experiments employing alloys the total amount of metal introduced was 0·3 mg. in 7 cases, 0·4 mg. in 4 and 0·5 mg. in a further 5 cases. The difference in dosage was not sufficiently marked to enable any fine discrimination in the reaction of the eye to varying dosage of metal. None the less as can be seen from Table II, the suggestion emerged that 0·3 mg. was probably better tolerated than 0·5 mg. This is parti-

cularly seen in the case of fundus reactions. In the case of aluminium implants the dose varied considerably, ranging from 0·3 mg. to 20 mg., and here the correlation between dosage and effect emerges more clearly. Four eyes became disorganised; the dosage to which they had been submitted was 4 mg., 10 mg., 3·32 mg., 20·0 mg.; whilst the slighter effects on the cornea, iris, and lens generally tended to coincide with smaller doses, though exceptions were observed.

There was also some difference in the reaction of the eye according to the site of implantation. In the case of the alloys only two experiments in vitreous implantation were carried out, 0·3 mg. being inserted in each case. It is noteworthy that one of these two eyes became disorganised, constituting the only disorganised eye in the experiments with alloys. The second eye with vitreous implantation, though not ending in disorganisation, also ran a severe course. Implantations of alloys into the anterior chamber appear to have given the milder reaction. None of the 14 eyes ended in disorganisation, only two showed a gross corneal reaction, and one a gross iris reaction, whilst none gave a gross lens reaction. Gross fundus changes were, however, present in 6 of these cases. In the case of implants of pure aluminium 2 disorganised eyes were noted out of 11 anterior chamber implants, and 2 out of 7 vitreous implants. Comparison is difficult as neither the dosage nor the time factor were uniform. What is significant is that with the larger doses the site of implantation did not seem to matter much: all the tissues of the eyes appeared to be involved in the reaction. With smaller fragments the suggestion emerges that with anterior chamber implants the anterior segment of the eye was more prone to be involved than the posterior segment, whilst the opposite held true for vitreous implants.

That the site of the implant influences the position of the reaction is seen most clearly from the distribution of the imprints. The 6 corneal imprints, the 12 iris imprints, and the 2 lens imprints all occurred with anterior chamber implants, whilst the 4 fundus imprints were all seen with vitreous implants. Contiguity rather than dosage appears to be the determining factor as is seen in the case of the 12 iris imprints. Here the dosage of the implant ranged between 0·5 mg. to 12 mg.

### 4.—Illustrative Experiments

The following illustrative experiments bring out the reactions observed with pure aluminium and with the alloys. The ocular reactions to increasing doses of aluminium inserted into the anterior chamber and into the vitreous are illustrated by five and

six observations respectively, whilst single instances are given of approximately equal doses of five different alloys inserted into the anterior chamber and there is one instance of an alloy inserted into the vitreous.

A.—INSERTION OF PURE ALUMINIUM

(1) *Into the anterior chamber.*

(*a*) Effect of 0·5 mg. observed for 4 months.

*Rabbit* 5. A fragment of 0·5 mg. of 99·9 per cent. pure aluminium was inserted into the left anterior chamber. Four months later the appearance was as in Fig. 4. The corneal scar was firmly healed, but included a black patch of iris pigment. Near the scar the iris shewed a grey irregular imprint at the former site of the fragment. The piece of metal had disappeared and could nowhere be seen.

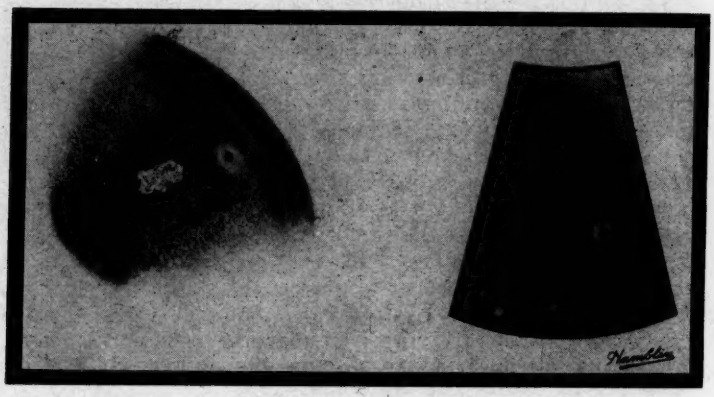

FIG. 4.

Rabbit No. 5. Appearance 4 months after implantation of 0·5 mg. pure aluminium into the anterior chamber.
(*a*) An "imprint" is seen on the iris. The metal itself has disappeared. Some iris pigment is visible in the incision scar.
(*b*) Pigmentary and necrotic changes are seen at the peripheral fundus.

The fundus shewed peripheral pigmentary changes and some small and necrotic white patches. Many lens opacities were visible.

(*b*) Effect of 4 mg. observed for 10 months.

*Rabbit* 13. Through a postero-superior corneal incision 4 mg. of 99·9 per cent. pure aluminium were inserted in 1 mg. fragments into the anterior chamber. Soon the corneal scar became vascularised. Two of the pieces of aluminium sank into the lens; the other two fell to the lower angle of the anterior chamber and

became covered with jelly and incrustation. After a while posterior synechiae formed and were followed by iris bombé.

Ten months after insertion the appearances were as in Fig. 5. The lower third of the cornea presented a grey opacity in its deep

FIG. 5.

Rabbit No. 13. Implantation of 4·0 mg. pure aluminium into the anterior chamber. Appearances after 10 months. The lower third of the cornea shows a grey opacity in its deep stroma. Opposite this area a jelly, derived from the foreign body, has previously formed. The corneal opacity shows superficial vascularisation. The iris shows severe inflammatory changes with extensive posterior synechiae and the formation of iris bombé.

stroma. This was the area which had been opposite the jelly previously formed. This area of cornea presented much superficial vascularisation, the fine newly formed vessels taking origin from the limbal vessels. There was also much superficial marginal vascularisation at the limbus above.

The corneal scar shewed fine vascularisation; and there was a broad anterior synechia attached to this entry scar.

In the lower angle of the anterior chamber lay the partially absorbed remains of one of the fragments, coated with white jelly and exudate.

In the pupillary area was a nodule of lens matter. This had a few fine vessels on its surface, which appeared to be rising from the anterior surface of the iris. The pupil was firmly adherent to the lens capsule, and was blocked with fibrous tissue. Much of the iris, particularly below, shewed iris bombé.

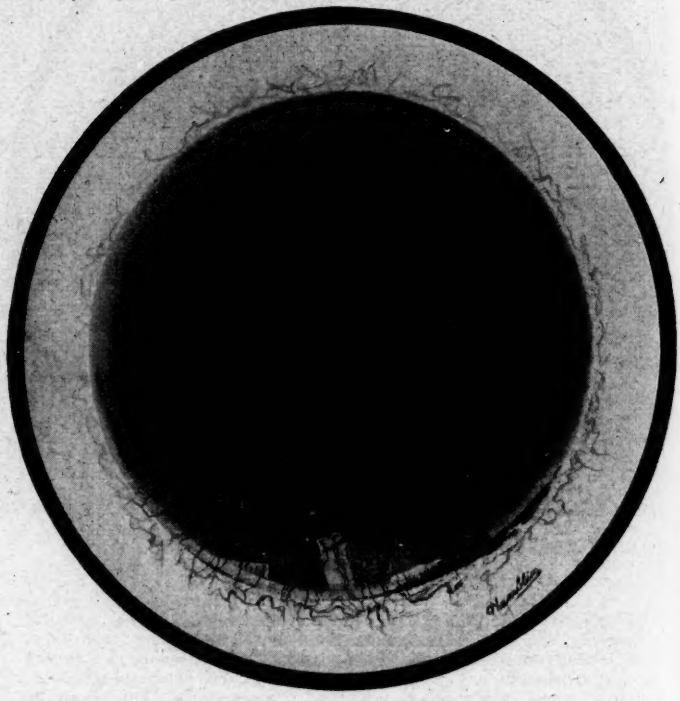

FIG. 6.

Rabbit No. 14. Implantation of 6·0 mg. pure aluminium into the anterior chamber. Effects seen at 10 months. The aluminium had been inserted in 6 fragments of 1 mg. each. There is diffuse opacification in the lower part of the cornea. Superficial vascularisation and increased limbal pigmentation are present. A corneal "imprint" is seen in the pupillary area. Transillumination showed the iris to be atrophic. Over the site of insertion of the metal a large grey iris imprint with pigmented margins is seen as shown in the upper part of the illustration.

(*c*) Effect of 6 mg. observed for 10 months.

*Rabbit* 14. Through a postero-superior corneal incision 6 mg. of 99·9 per cent. pure aluminium was inserted into the left anterior chamber in fragments of 1 mg. each. Ten months later the appearances were as in Fig. 6. The lower portion of cornea shewed an opacity of a diffuse nature in its deeper layers near the angle of the anterior chamber. This area of cornea shewed superficial vascularisation arising from the limbus and confined to the area of the opacity. Limbal pigmentation was increased and the pigmented patches encroached at some points on to the corneal epithelium. Opposite the pupillary area there was a posterior corneal imprint of irregular shape. The iris was atrophic as shewn on transillumination. Near the site of insertion of the metal was a large grey iris imprint with pigmented margins. The

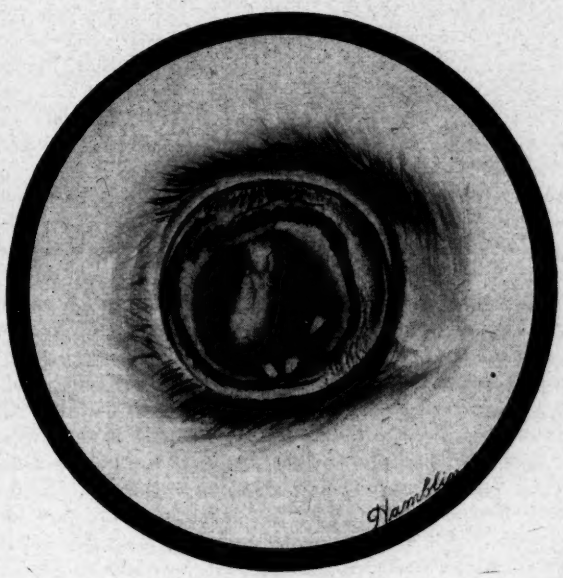

FIG. 7.

Rabbit No. 16. Implantation of 10 mg. pure aluminium into the anterior chamber of right eye. Changes seen after 10 months. The aluminium had been inserted in 10 pieces of 1 mg. each. After undergoing the milder changes seen in the earlier cases, including pathological fundus changes, the eye became enlarged simulating buphthalmos. The corneal diameters measured 19 mm. Diffuse oedema of the corneal epithelium and an interstitial keratitis with much vascularisation are present. The conjunctiva is heavily vascularised.

lens shewed many dots and striae. In the lower angle of the anterior chamber some of the metallic fragments could be seen coated with exudate and jelly, and dotted here and there with pigment.

(*d*) Effect of 10 mg. and 8 mg. respectively observed for 10 months in the two eyes of the same animal.

*Rabbit 16*. Under nembutal anaesthesia 10 pieces each weighing 1 mg. of 99·9 per cent. pure aluminium were inserted into the right anterior chamber, and 8 similar pieces into the left.

In the right eye the metal underwent the usual changes of becoming coated with white material and jelly, vascularisation and absorption. Iris and corneal imprints formed. Some of the bits of metal sank into the iris stroma. Pathological fundus changes appeared. Ten months after implantation the eye presented the appearances shewn in Fig. 7. The eye was now diffusely enlarged and looking superficially like a case of buphthalmos, though closer inspection shewed that the detailed appearances differed and were rather those of a general staphyloma. The corneal diameter was 19 mm. There was a diffuse oedema of the corneal epithelium and an interstitial keratitis with much vascularisation. Through the cornea could be seen masses of gelatinous material and fragmented pieces of metal. There was much increase of pigmentation at the limbus. The conjunctiva was heavily vascularised. Transillumination shewed that the iris was atrophic and that there were anterior synechiae. The lens and fundus were not visible at this stage.

Meanwhile progress of the changes had been much slower in the left eye. Appearances ten months after insertion of fragments were as in Fig. 8. Here there was a large posterior corneal imprint opposite the pupillary area, with a diffuse pigmented plaque on the posterior corneal surface. Several pieces of metal covered with white exudate and jelly could be seen at the lower angle of the anterior chamber. Opposite the fragments the cornea was opaque on its deep surface and vascularised superficially. The metallic fragments shewed signs of partial absorption, and powdery metal could be seen on the anterior surface of the iris which was atrophic. The lens shewed streaky opacities. The left fundus shewed much diffuse pigmentation, which was considered pathological.

(2) *Into the vitreous.*

(*a*) Effect of 0·9 mg. with picture at 13 weeks.

*Rabbit* 8. Fragments of 99·9 per cent. pure aluminium weighing 0·9 mg. were inserted through scleral puncture into the vitreous. Thirteen weeks later the appearances were as in Fig. 9. The fragment lay on the peripheral retina covered with a greyish-white coat. The fundus generally shewed a large number of small

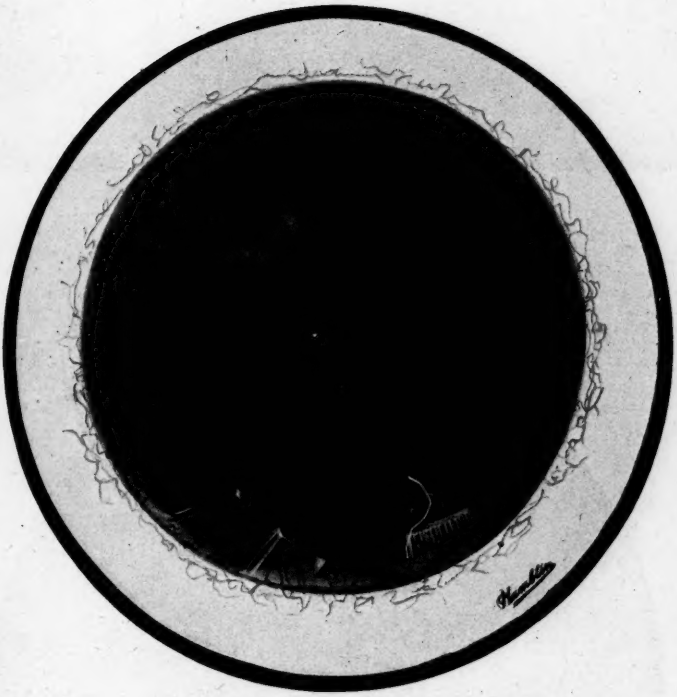

FIG. 8.

Left eye of the same rabbit. (Rabbit No. 16.) Here 8 strips of aluminium 1 mg. each had been inserted into the anterior chamber. The reaction, observed for the same period of 10 months, ran a milder course. A large corneal "imprint" was present in the pupillary area with a diffuse pigmented plaque on the posterior corneal surface. Several pieces of metal covered with white exudate and jelly can be seen at the lower angle of the anterior chamber. Opposite these fragments the cornea tends to be opaque on its deep surface and vascularised superficially. Some disintegration of the metal can be seen, as also white powdery débris on the anterior surface of the iris which is atrophic. Lens opacities are present.

FIG. 9.

Rabbit No. 8. Implantation of 0·9 mg. pure aluminium into the vitreous. Changes observed after 13 weeks. The fragment is seen to lie peripherally on the retina, and shows a greyish white coat. A number of small necrotic white patches are seen throughout the fundus. The inset shows the striae which were seen in the lens of the other eye.

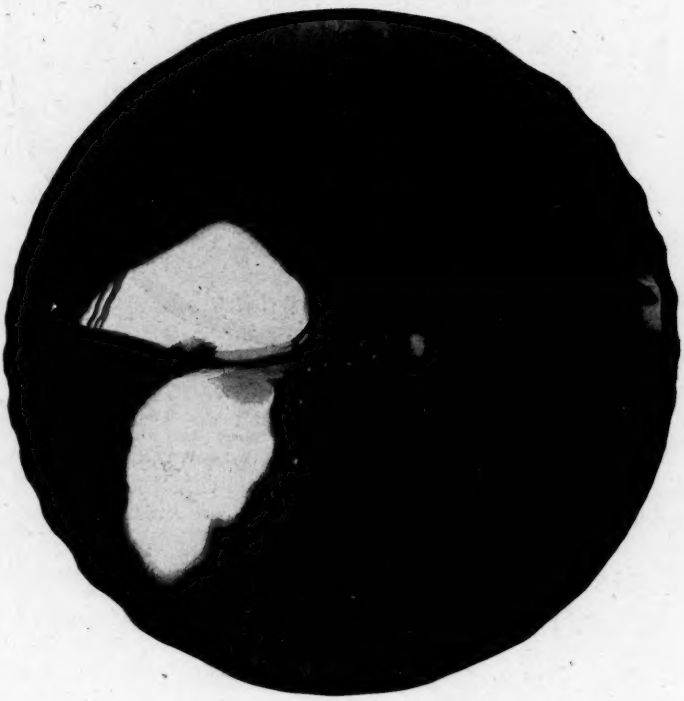

*FIG. 13.*

Rabbit 18, left eye. Insertion of one piece of aluminium weighing 6·64 mg. into the vitreous. Appearances observed at 7 months. Two large white imprints are seen with a smaller one at the end of the bent strip of metal. The metal itself is eroded and coated with white exudate. A strand of gelatinous material extends from the metal to the junction of the two main imprints. Part of the metal can be seen in this strand and scattered over the nearby fundus. There was pathological pigmentation in the periphery of the fundus.

necrotic white patches. The inset to the figure shews the striae which were seen in the lens of the other eye.

Later on the metal shifted leaving a retinal imprint. Pigmentation increased in the fundus.

(*b*) Effect of 3·32 mg. and 4·98 mg. with illustrations at 9 months and 7 months respectively in the two eyes of the same rabbit.

*Rabbit* 17. Four fragments of 99·9 per cent. pure aluminium each weighing 0·83 mg. were inserted into the right vitreous through an antero-superior scleral puncture behind the equator of the eye. There was much difficulty in making the fragments

FIG. 10.

*Rabbit No. 17, right eye.* Implantation of 3·32 mg. of pure aluminium in 4 fragments into the vitreous. Changes observed after 9 months. The eye is shrinking; the corneal diameter measured 12 mm. as opposed to 14 mm. for its fellow. Marked superficial keratitis of the zonular type. The limbus is vascularised and the vessels extend on to the corneal lesion. The iris is atrophied. Posterior synechiae and iris bombé are present.

remain in position, and it is possible that the lens might have been touched by the forceps.

A month later the lens began to shew opacities. Gradually it became opaque, the iris atrophied, and iris bombé occurred.

Nine months after operation the appearances were as in Fig. 10. The eye was shrinking; the cornea measured 12 mm. as opposed to 14 mm. for its fellow. There was a well marked superficial keratitis of the zonular type. The limbus was vascularised. Superficial fine vessels passed from the limbus to the patch of keratitis. The iris was much atrophied. There were posterior synechiae all around the pupillary ring, and some proliferation of iris pigment was noted on the anterior lens capsule. Iris bombé was present. There was a chalky white cataract.

Meanwhile events in the left eye had taken a somewhat different course. Here 6 pieces of 99·9 per cent. pure aluminium each weighing 0·83 mg. had been uneventfully inserted through a postero-superior Graefe puncture behind the equator. Gradually the corneal periphery became vascularised and the iris became atrophic. Lens opacities developed, more particularly in the posterior lens cortex. Some of the pieces of metal were covered first with white coating, and then gradually absorbed. Others shewed comparatively little change. Seven months after the initial operation the fundus appearances were as in Fig. 11. The disc

FIG. 11.

Rabbit No. 17, left eye. Implantation of 6 pieces of pure aluminium each weighing 0·83 mg. into the vitreous. Appearances as seen after 7 months. The disc is largely blurred by vitreous haze. Fibrous bands with arborescent blood vessels come forward into the vitreous. There is much pigmentary change. The retinal "imprint," marking the site formerly occupied by a bit of metal, is seen on a level with the disc.

was seen with some difficulty through a vitreous haze. There were fibrous bands with arborescent blood-vessels in the vitreous, constituting the picture of retinitis proliferans. The fundus was heavily pigmented, especially in its periphery. The degree of pigmentation was more than initially present, and was considered pathological. Near the disc there was a darkly pigmented patch at the site formerly occupied by a piece of metal. It was considered a retinal imprint.

The vitreous opacities gradually increased until at length the fundus was completely obscured. The iris slowly became depigmented above the pupil.

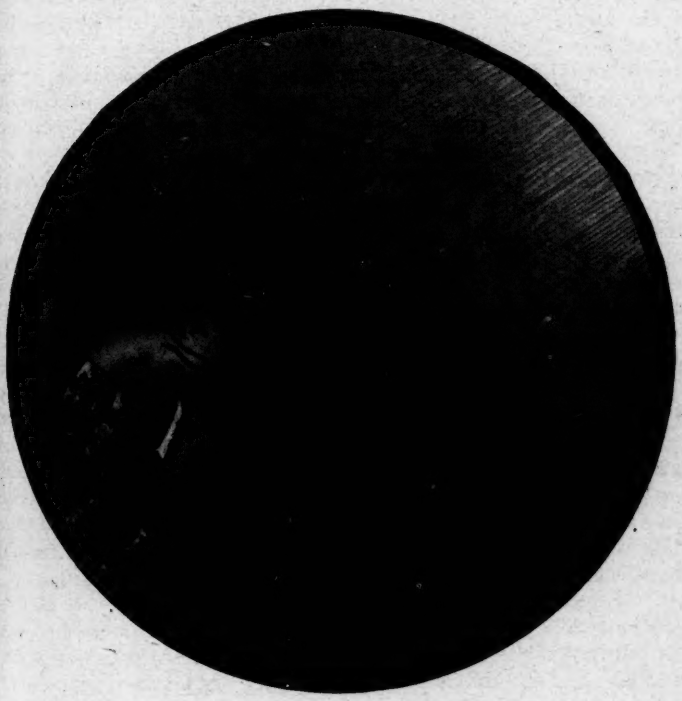

FIG. 12.

Rabbit No. 18, right eye. Implantation of 10 fragments of 0·83 mg. each pure aluminium into the vitreous. Appearances after 7 months. Four fragments of metal can be seen in the area shown in the illustration. A white film was present over some of them. One fragment is dotted with flecks of haemorrhage. A retinal "imprint" is seen just above the fragments; it is bordered by pigment. A fresh pigmented patch (not shown in the illustration) was present above the disc.

(*c*) Effect of 8·3 mg. in 10 fragments and of a single fragment of 6·64 mg. observed for 7 months in the two eyes of the same rabbit.

*Rabbit* 18. Ten pieces each weighing 0·83 mg. of 99·9 per cent. pure aluminium were inserted through a postero-superior Graefe puncture into the vitreous of the right eye. Gradually the corneal periphery became vascularised, and in the next few months the iris gradually atrophied, so that it transilluminated generally, with particularly atrophic patches near the pupillary margin. The lens developed streaky opacities. The fundus appearances 7 months after insertion of fragments are shewn in part in Fig. 12. In the area shewn in the figure 4 fragments of metal could be seen massed on the retinal surface. Some of the pieces were covered with a white film. One was dotted with flecks of haemorrhage. A retinal imprint could be seen as a greyish-white patch, bordered with a line of dark pigment. Elsewhere in the fundus (not shewn in the figure) could be seen the scar of the insertion wound. There was a large fresh pigmented patch above the disc.

Meanwhile the effect on the left eye was tested by the insertion of a single piece of 99·9 per cent. pure aluminium in strip form weighing 6·64 mg. (equivalent to 8 of the 0·83 fragments used separately on the other eye). Gradually the cornea became vascularised peripherally and the iris atrophic. Lens opacities developed. Seven months later the fundus shewed two large white retinal imprints which had been exposed by a recent shift of the metallic strip. A third imprint could be seen at the opposite end of the strip. In detail the appearances were those shown in Fig. 13 where the strip looks somewhat foreshortened. The strip was eroded and coated with white exudate. The two lower imprints were covered with white and necrotic material. The upper imprint shewed fresh vascularisation at one side. A strand of gelatinous material ran to the junction of the two imprints. Powdery metal could be seen in the strand and scattered over the nearby fundus. There was pathological pigmentation in the fundus periphery.

(*d*) Effect of 20 mg. observed for 6 months.

*Rabbit* 23. 20 mg. of 99·9 per cent. pure aluminium were inserted into the right vitreous through a postero-superior scleral puncture. Six months later the cornea was vascularised and showed zonular degeneration. Other areas of cornea shewed cholesterin crystal deposits in the stroma. The cornea was ectatic and only measured 9 mm. across as opposed to 13 mm. in the other eye. The appearance of the iris is shewn in Fig. 14. The iris shewed a central funnel-shaped depression with two vascularised white nodules projecting centrally in the pupillary area. The rest of the iris was in a condition of iris bombé and was much atrophied.

B.—INSERTION OF ALUMINIUM ALLOYS

(1) *Into the anterior chamber.*

(*a*) Effect of 0·5 mg. aluminium-copper (group 2), observed for 7 months.

*Rabbit* 12. A piece of aluminium-copper (group 2) weighing 0.5 mg. was inserted into the left anterior chamber. Eleven weeks later the appearance was as in Fig. 15. The limbus was somewhat vascularised. Above the pupil was a grey iris imprint. This was dotted with white-coated metallic powder from the fragment. Fine

FIG. 14.

Rabbit No. 23. Implantation of 20 mg. of pure aluminium into the vitreous. Appearance of the iris after 6 months. The eye showed extensive degenerative changes. The cornea was ectatic, vascularised and developed zonular degeneration. Elsewhere in the cornea cholesterin crystals could be seen in the stroma. The iris, shown in the illustration, gave the appearance of a central funnel-shaped depression with two vascularised white nodules projecting centrally in the pupillary area. There was extensive atrophy and iris bombé was present.

capillary vessels could be seen in the superficial layers of the cornea opposite the imprint, though the latter did not seem to be directly vascularised. Near the pupillary margin lay other powdery fragments of the metal. There were posterior synechiae and some iris pigment on the anterior lens capsule. The lens shewed streak, spiral and whorl opacities.

The main fragment lay below the pupil and adherent to the posterior corneal surface. The metal was partly absorbed and was encrusted with a yellowish-white covering. The cornea opposite the metal was slightly hazy and its superficial layers were vascularised.

Not long after this picture the metal again shifted, this time to near the pupillary margin. Here seven months after the insertion of the metal the appearances shewn were those of Fig. 16.

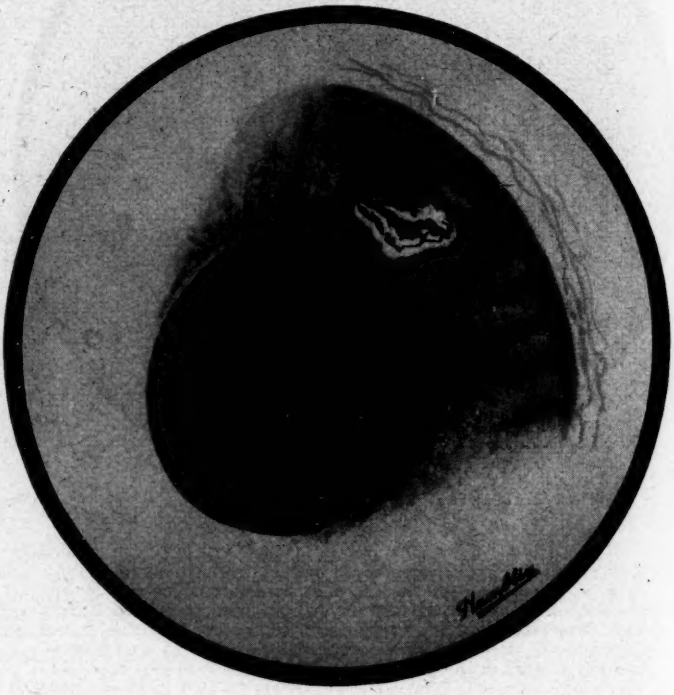

FIG. 17.

Rabbit No. 11. A fragment of aluminium-magnesium is adherent to the posterior surface of the cornea. The posterior surface of the metal is thickly covered by a white coating, which encroaches upon the corneal endothelium. The lens shows streaky cortical opacities.

FIG. 15.

Rabbit No. 12. Insertion of 0·5 mg. aluminium-copper into the anterior chamber. Appearance after 11 weeks. The limbus is somewhat vascularised. A grey "imprint" dotted with white coated metallic powder from the fragment is seen on the iris above the pupil. The cornea above the "imprint" shows slight vascularisation. In the pupillary margin powdery fragments of the metal are seen. There are posterior synechiae and some iris pigment on the anterior lens capsule, and opacities are present in the lens itself. The metal itself is seen below the pupil. It is partially absorbed and encrusted with a yellowish white covering. The overlying cornea is slightly hazy and vascularised.

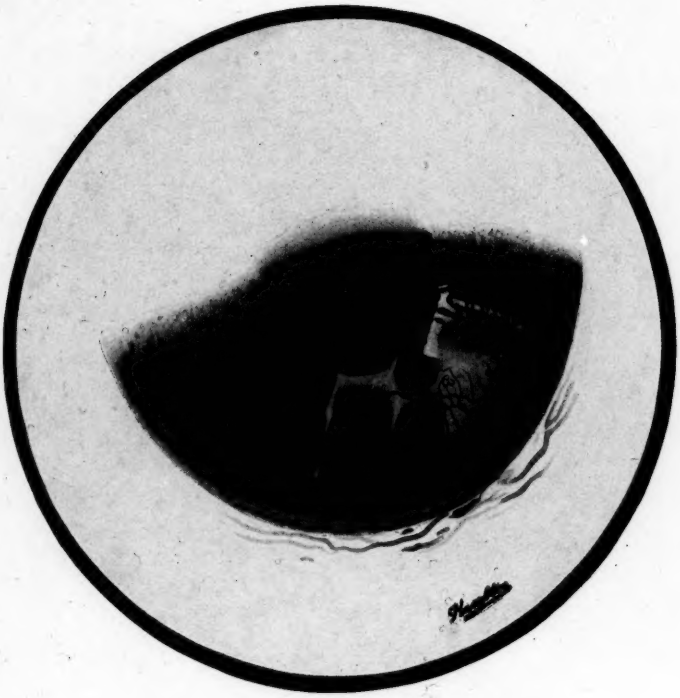

FIG. 16.

The same eye at 7 months. The fragment had shifted exposing an underlying "imprint" surrounded by fibrous tissue, which extends to the anterior lens capsule. The metal itself is in a more advanced stage of disintegration, and is covered by yellowish white coating. The lens shows opacities and polychromatic lustre. Some fragmentation of the metal can be seen.

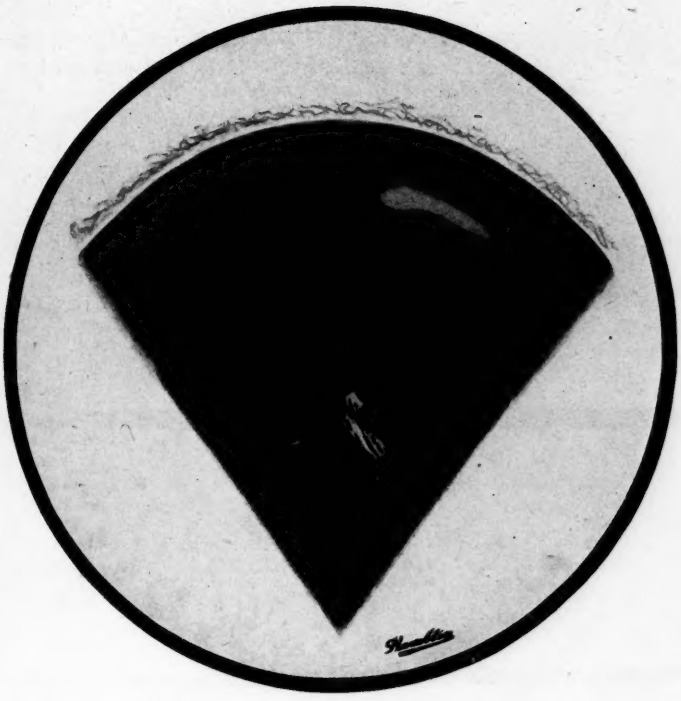

FIG. 18.

Rabbit No. 1. An aluminium-copper fragment is seen in the anterior chamber. The fragment had fallen down upon the anterior lens capsule where there was a capsular opacity, also a superficial lens opacity. A broad pigmented synechia connected the opacity to the pupillary margin.
The metal itself was partly absorbed and fragmented. In part the metal showed a white coating. The limbus was vascularised. The corneal scar had healed.

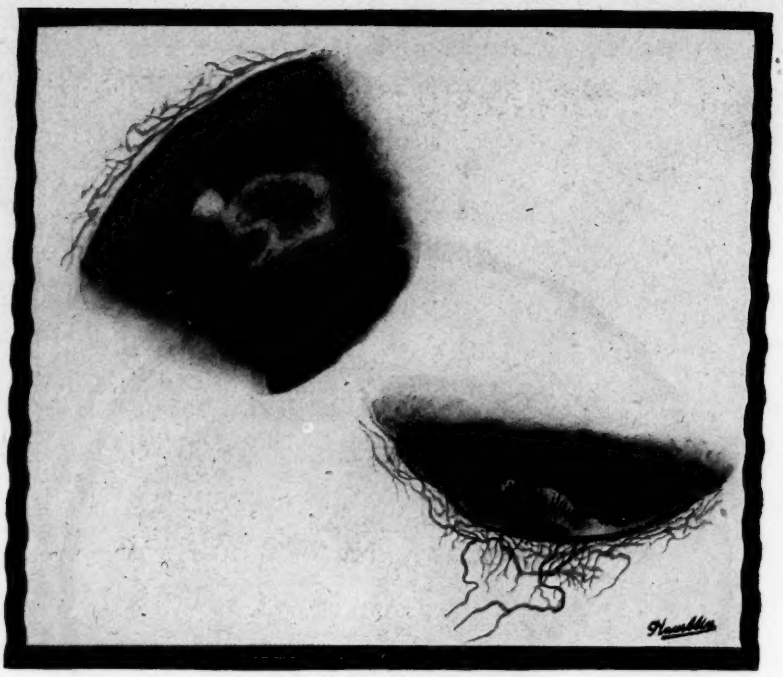

FIG. 20.

Rabbit No. 4. Insertion of 0·5 mg. aluminium-nickel into the anterior chamber. Appearances after 5 months. Above and anteriorly an iris "imprint" is seen. On its surface small fragments of powdery metal are present. The metal itself had sunk to the lower angle of the anterior chamber and is coated with yellowish white exudate. There is some limbal injection and fine capillary vascularisation of the superficial cornea of this area.

FIG. 21.

Rabbit No. 9. Insertion of 0·3 mg. aluminium-nickel into the vitreous. Appearances at three months. The lens shows posterior cortical opacities and some blood on its posterior surface. On the fundus the metallic fragment can be seen at right angles to an underlying "imprint," the site of its original position.

On the back of the cornea in the previous site of the metal was a faint grey imprint. Superficially in the cornea there was fine vascularisation in this region. The subjacent iris shewed a greyish-yellow imprint, surrounded on the iris by lines of fibrous tissue, which extended to the anterior lens capsule.

The cornea was superficially vascularised over the new site of the metal; and there was also a nebula. The metal itself lay at the pupillary margin and was dotted over with pigment. The fragment was mainly eroded and was covered with a yellowish-white coating. The lens shewed opacities and polychromatic lustre. The fundus shewed pigmentation thought to be pathological.

(*b*) Effect of 0·5 mg. aluminium magnesium observed for 9 weeks.

*Rabbit* 11. A fragment of aluminium magnesium (group 3) weighing 0·5 mg. was inserted into the left anterior chamber. The appearance 9 weeks later was as in Fig. 17. The metallic fragment was adherent to the posterior surface of the cornea. The area in contact with cornea was relatively bright. The posterior surface of the metal was thickly covered by a white coating. The lens shewed streaky cortical opacities. There was considerable fundus pigmentation.

Later the metal eroded forwards into the corneal stroma and gradually became fragmented. There were numerous lens changes, and gross fundus pigmentary changes.

(*c*) Effect of 0·4 mg. of aluminium-copper, observed for 18 weeks.

*Rabbit* 1. In this rabbit 0·4 mg. of aluminium-copper (group 6) alloy was inserted into the anterior chamber. Eighteen weeks later the appearance was as shewn in Fig. 18. There was limbal vascularisation. The corneal scar had firmly healed. The fragment had slipped down on to the anterior lens capsule, where there was a capsular opacity with some opacity of the subjacent lens matter. This opacity was connected by a broad pigmented and vascularised synechia to the pupillary margin. The metal was covered with a white coating, and was partially absorbed. Some fragmentation of metal had taken place, and white coated small fragments were visible on the surface of the lens opacity and on the synechia. Examination with the slit-lamp shewed polychromatic lens lustre, and there were pathological fundus changes.

(*d*) Effect of 0·4 mg. aluminium silicon observed for 3 months.

*Rabbit* 7. Here a fragment weighing 0·4 mg. of aluminium silicon (group 8) was inserted into the R. anterior chamber. Three months later the appearance was as in Fig. 19. The fragment was partially eroded and had a coat of powdery-white material with gelatinous material on the anterior surface peripherally. New

vessels rose from the iris in this region and passed across the front of the metal. The pupillary margin was slightly everted and adherent to the posterior surface of the metal. Dot and streak-shaped lens opacities were visible in the lens.

Later on the metal absorbed almost completely, an imprint shewed on the iris deep to the fragment, lens opacities increased, and the fundus shewed pathological changes.

(*e*) Effect of 0·5 mg. of aluminium-zinc with picture drawn at 5 months.

*Rabbit* 4. Five months after 0·5 mg. of aluminium zinc (group 9) had been inserted into the anterior chamber the appearance was as in Fig. 20. Above and anteriorly the iris shewed a greyish-

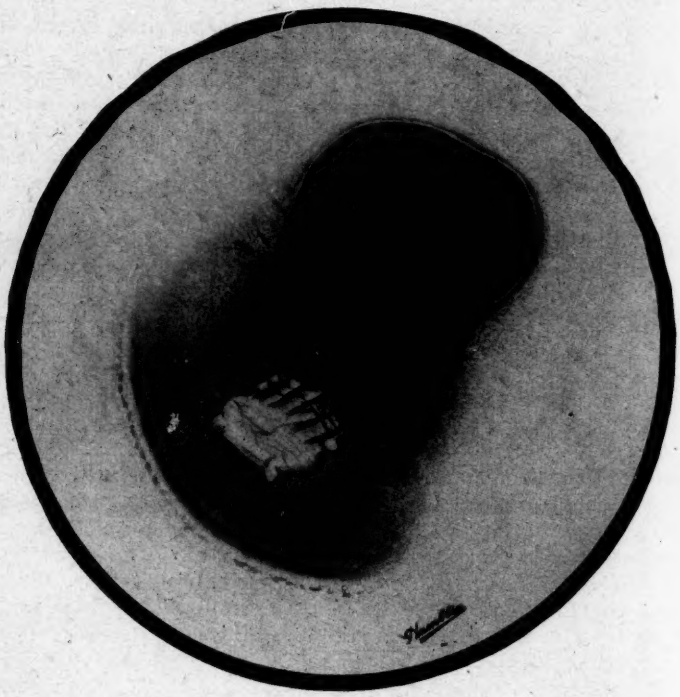

FIG. 19.

Rabbit No. 7. Implantation of 0·4 mg. aluminium-silicon into the anterior chamber. Appearances after three months. The fragment is partially eroded. Some fragmentation and formation of gelatinous material on its anterior surface is seen at the end away from the pupil. Iris vessels pass in front of the metal. The pupillary margin is slightly distorted, and adherent to the posterior surface of the metal. Opacities are present in the lens.

white imprint. On the surface of the imprint could be seen small fragments of powdery metal. There was slight vascularisation of the superficial cornea near the limbus. The actual metallic fragment had dropped to the lower angle of the anterior chamber, where it lay coated with yellowish-white exudate. There was enhanced vascularity of the limbus opposite the metal, and fine capillary vascularisation of the superficial cornea of this area.

The metal became deeply embedded in the iris, which was vascularised in this area. Peripheral pigmentary changes appeared in the fundus.

(2) *Into the vitreous.*

(*a*) Effect of 0·3 mg. aluminium-nickel-copper with picture drawn at 3 months.

*Rabbit* 9. A square fragment of aluminium—nickel-copper (group 4) weighing 0·3 mg. was inserted without difficulty into the vitreous through a scleral puncture (L. eye). There was no appreciable bleeding and the fragment was at once easily visible ophthalmoscopically. Three months later the appearances were as in Fig. 21. The lens shewed posterior cortical lens opacities. There was some blood on the posterior surface of the lens. Fundus examination shewed that the metallic fragment was completely coated with a whitish-yellow covering. The fragment had been dislodged by the animal's movements and lay at right angles to its original position. Deep to the fragment could be seen a retinal imprint at the original site.

Atrophic patches appeared in the iris. Lens opacities increased. The fundus shewed retinitis proliferans.

## 5.—Histological Findings

Twenty-nine eyes with intra-ocular foreign bodies and two control eyes were available for histological examination. The eyes were preserved in formol saline and later bisected for paraffin sections to be made. A serious difficulty was that the numerous small metallic bodies in the eyes rendered it difficult to cut sections. Even the minute fragments in many of the corneae were found to destroy instantly the cutting edge of the microtome knife, so that there was gross destruction and tearing of the surrounding tissues. This trouble was overcome to some extent by picking out any foreign bodies which were noted in the paraffin block; but this process in itself tended to spoil the ocular tissues immediately adjacent to the fragments, while it was usually found that some minute fragments were overlooked. In order to obviate this, many of the sections were cut rather thicker than usual. This helped to produce a complete section; but often at the expense of the finer histological details. Moreover, many of the sections were found with torn or folded corneae, damaged lenses, and other imperfections.

Much time was spent in endeavours to overcome these difficulties.

An attempt to work out a technique in which the metallic fragments might be removed by the use of some selective solvent, was unsuccessful. It seemed that the best course was to reject those parts of the sections adjacent to the foreign bodies as liable to be vitiated by accidental damage. Conclusions were based on sections somewhat distant from the fragments of metal.

In correlating the sections with the clinical observations on the experiments, it has to be remembered that a considerable time had elapsed in most cases between the original experiments and the acute immediate changes, and the final disposal of the animal.

*The more significant histological changes*

*The cornea.*—There was hyalinization in two cases (1, r and 1). In three cases the section passed through the healed corneal scar (5, r; 20, 1; 22, r). The cornea was frequently vascularised, completely sometimes (17, r; 23, r), and in other cases peripherally (17, 1; 20, r). In two cases plaques were observed in the cornea (13, 1; 23, r) their structure being vascular or fibrous. In one case (17, r) the cornea shewed peripheral wrinkling.

The anterior chamber shewed in two cases metallic fragments and exudate (14, r; 13, 1) and in one case fibrous bands (13, 1).

*The iris.*—A large number of pathological changes were observed. The iris shewed marked thickening in two cases (1, r; 7, 1), in one case (1, L) there was round-celled infiltration with foreign body giant cells. In many instances the iris shewed atrophy, partial in 5 cases (4, r; 13, r; 16, r; 22, r; 23, 1), well-marked in one (5, r), complete in 8 cases (11, r; 14, r; 14, 1; 16, 1; 17, r and 1; 18, r and 1). There was fibrosis in two cases (7, 1; 17, 1). Anterior synechiae were noted in 3 cases (14, 1; 16, r; 23, r). Exudate was noted behind the iris in one case (17, r). Abnormal pigment distribution was seen in 10 cases; this was superficial in two cases (17, 1; 22, r), patchy in three (4, r; 1, r; 16, r), and widespread and diffuse in five cases (5, r; 10, r; 13, r; 14, r; 17, r).

*The lens.*—As already stated the lens had frequently suffered in the cutting of the sections. In one case the lens seemed to be disorganised and calcified (9, 1), and in 4 cases (9, 1; 13, 1; 17, 1; 23, 1) it was surrounded with exudate and incorporated with the ciliary body.

*The vitreous chamber* was filled with débris in one case (18, 1).

*The retina.*—In three cases (1, r and 1; 23, r) the retina was degenerate. There was loss of structure of the nervous elements in two cases (5, r; 11, 1). Cystic degeneration was observed in the peripheral retina in two instances (7, r; 11, r). The retina might be atrophied in a local area (14, r), or more usually complete (8 cases: 5, r and 1; 7, r; 8, r and 1; 9, 1; 10, r; 18, 1). Fibrosis was observed in one case (9, 1), organisation in another (7, 1), and in one instance there was retinitis proliferans (17, 1).

More active changes included choroidoretinitis (7, l), cellular infiltration (10, r), active exudation in 6 cases (10, l; 11, l; 13, r; 14, r; 16, r; 23, l), disorganisation in two cases (10, l; 11, r).

*The choroid.*—Abnormal features were frequently seen. Exudate was noted in 4 cases (1, r and l; 16, l; 23, r). Thinning was noted in one case (5, r), and excessive vascularisation in another (13, r).

*Optic nerve.*—Degenerative changes were noted in one case (4, l).

Taking the eye as a whole, although defects in the preparation of the sections prevented a complete review, the histological findings were explicit enough to shew that aluminium was not inert in the eye: it caused widespread low-grade inflammatory and degenerative changes, seen histologically as well as clinically.

Detailed histological reports are shown in Appendix II by Major J. O. Oliver.

*Distribution of Aluminium in the Ocular Tissues*

Since pathological changes from aluminium are widespread in the eye, and as it has also been noted that fragments of pure aluminium could apparently be completely dissolved in an eye (Case 22, r), the question arose as to how extensively the aluminium was disseminated through the ocular tissues.

It was at first hoped to utilise the intensely coloured red "lake" produced by aluminium salts with alizarinsulphonic acid as a means of tracing the aluminium, but consistent results could not be obtained.

A second method which utilises the red colour formed when aluminium salts combine with aurintricarboxylic acid was almost as disappointing. This colour reaction has to take place at a pH of 4·9 and is developed by heating at a temperature of 70—78 degrees C. This staining method proved uncertain at one time, producing red staining areas in the section, while subsequently similar sections from the same block, treated in apparently similar fashion, failed to stain. In the successful stainings the deeper layers of the cornea, the ciliary body, and the inner nuclear layers of the retina appeared to shew staining for aluminium most markedly. But the results were insufficiently constant to be considered a valid indication of the true distribution of the aluminium in the ocular tissues.

Whilst local changes near the fragments may be regarded as being directly due to the action of aluminium, it must be left an open question whether the more remote changes are due to aluminium possibly disseminated through the ocular tissues, or to some indirect toxic effect.

## 6.—Discussion

Only scanty clinical records are available: three anterior chamber implantations (Jess, Fricke, Hesky), one anterior chamber and lens (Fricke), and two vitreous implantations (Savin). In one of Savin's cases the identification of aluminium was on strong presumptive evidence only. The animal case records are all upon rabbits and include 35 anterior chamber implantations (27 Savin, 8 Fontana) and 13 vitreous chamber implantations (9 Savin, 4 Fontana). The experimental work of Jess and Mielke is not recorded in sufficient detail for critical assessment.

There is close agreement between the animal and human case records. Jess's case shewed fragmentation of the metal, depigmentation of the pupillary margin near the foreign body, pigment deposition at the root of the iris, and a faint lens opacity. All these points were frequently demonstrable in the experimental animals. Fricke's first case shewed fragmentation of metal in the right eye, as frequently noted in the animals; his second case shewed fragmentation of the metal, lens opacities, and iridocyclitis; all these changes too were observed in the present experimental study. Hesky's case shewed corneal opacity, and iritis, both being changes found in the animal series. Likewise the changes in the vitreous observed by Savin clinically (coating of the metal, imprint formation, and some retinal pigmentation in one case, and more severe changes in the second: coating of the metal, mild iridocyclitis, vitreous opacities, localised imprints, and pigmentary changes in the adjacent retina) were also observed in the experimental animal. Whilst the changes observed in man so far — including changes in the metallic fragments, imprint formation and pigment deposition in adjacent ocular tissues—are paralleled in the experimental animal, the more remote changes seen in the rabbit have not as yet been noted in human eyes.

In the experimental series no tangible difference could be established between the effects of pure aluminium as opposed to aluminium alloys. Both groups give the same end result: lens opacities, quiet inflammatory iris changes, atrophy of the iris, choroiditis, choroidal and retinal degeneration and atrophy, retinitis proliferans, and also possibly vascularisation of various parts of the eye. There is some suggestion that with equal dosage, the presence of aluminium, or its alloys, is more deleterious when it is in the vitreous than in the anterior chamber. There is, however, no suggestion that particles in the anterior chamber are well tolerated. The size of the fragment seems to be a more definite consideration: the larger fragments are distinctly less tolerated than smaller fragments.

Aluminium and its alloys produce early effects in the adjacent tissues, but that widespread changes occur is clear from the almost

constant presence of fundus lesions, no matter what the size or position of the fragment be. Though aluminium and its alloys are not so destructive to the eye as iron and steel, these metallic intra-ocular foreign bodies call for operative removal. The technical difficulties for such removal are, however, such that it would seem that in individual cases an opportunist policy has to be adopted. It would seem that where the fragments are readily accessible, as in the anterior chamber, their removal should be attempted. Intravitreal fragments are probably best left alone except where their size is such that the loss of the eye is inevitable, if an expectant policy is adopted.

## Summary

The literature of intra-ocular aluminium is reviewed. A case is reported in which a piece of " aluminium zinc " (or possibly zinc base aluminium) was observed over a period of three years as it lay on the retina of an only eye. The metal was at first bright and silvery. Later it became coated with a white cover, probably of aluminium hydroxide. The fragment shifted twice, each time leaving a retinal " imprint," before eventually disintegrating into white powder. A second case behaved similarly.

Twenty-five implantations of aluminium and aluminium alloy fragments were made into the anterior chambers of rabbits by a standardised technique; and 9 vitreous chamber implantations. There was no clinical difference in the behaviour of pure aluminium and various alloys. Doses varying from 0·3 mg. to 20 mg. were used; the ocular reaction tended to be more severe with the higher doses.

The fragments were observed to become coated with white powder, with yellowish exudate, with fibrin, or in late cases with jelly. A late change often seen was powdering and fragmentation of the metallic fragment. In 6 cases the fragment was completely absorbed.

Common local changes were necrotic " imprints " left by the metal; of these 6 imprints were corneal, 12 on the iris (9 grey, 2 white, 1 necrotic), 2 in the lens, 4 in the fundus.

General ocular effects on the eye included lens opacities in 28 eyes, striae, dots, vacuoles, and irregular opacities; these lens opacities were occasionally accompanied by polychromatic lustre. There were 5 anterior capsular opacities, 6 anterior cortical, 4 posterior cortical, 2 capsular imprints, and 3 complete cataracts.

Quiet inflammatory changes in the uveal tract were frequent. These included 10 cases of posterior synechiae, 2 cases of iris bombé, and 14 cases of iris atrophy.

Other changes included pathological fundus pigmentation in 23 cases, 6 cases of localised choroiditis and 3 of retinitis proliferans.

Pathological vascularisation, not reported in the literature in human cases, occurred often in the animals. It is uncertain whether the reaction is specific for aluminium.

Among other oddities were noted 2 cases of bullous keratitis, 1 staphylomatous eye (false buphthalmos), 2 cases of zonular keratitis, 1 interstitial keratitis, 1 deep keratitis, 2 pigmented corneae, 1 pigmented limbus, 2 cases of folds in Descemet's membrane.

Histological investigations were hampered by technical difficulties. The changes observed were such as would have been expected from the clinical findings. They included hyalinisation and vascularisation of the cornea, iritis and iris atrophy, abnormal iris pigmentation. Retinal and choroidal pathological changes were noted in many instances. Abortive attempts were made to trace the distribution of the aluminium through the tissues by staining reagents.

On the clinical and experimental evidence it is concluded that the eye is by no means inert to aluminium.

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## APPENDIX I*

### SUMMARY OF PROTOCOLS

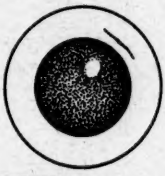
## *RABBIT. Nº 1.*

**1.** 27.9.42.

*Left eye – An oblique incision was made through the cornea at A. – A piece of Al-Cu group 6 alloy (12% copper) was inserted by curved iris forceps.*
*The same technique was repeated on the Right eye*

**2.** 28.9.42.

*Right eye - shows faint exudate over the F.B Entry wound is clear A white film passes to the edge of the iris.*



*Left eye shows the F.B. lying on the lens capsule which is slightly opaque. Faint white film over F.B*

**3.** 4.1.43

*Right eye -*
*1. scar clear*
*2. metal coated*
*3. fibrinous attachment to the iris*
*4. small opacity of the lens capsule.*

*Left eye -*
*1. anterior synechia to scar*
*2. white coat on metal*
*3. anterior capsular opacity*
*4. vascularisation of fibrinous adhesion of metal to iris*

**4** 7.1.43.

*Right eye -*
*1. Scar clear*
*2. metal coated & embedded in anterior capsule.*
*3. peripheral chorioido-retinitis*

*Left eye -*
*1 anterior synechia to scar with small glistening FBs in it ? metal*
*2. ant. capsular lens opacity with the FB on it and several scattered pieces of metal*
*Iris discoloured. Scattered jelly over FB - Folds in Descemets*

**5.** 16.5.43.

*Right eye -*
*1. there is bullous keratitis and fine keratic precipitates.*
*2. white mass at site of FB iris adjacent to it*
*3. imprint in the lens*
*4. there are some necrotic areas in the fundus at about 4 o'clock*

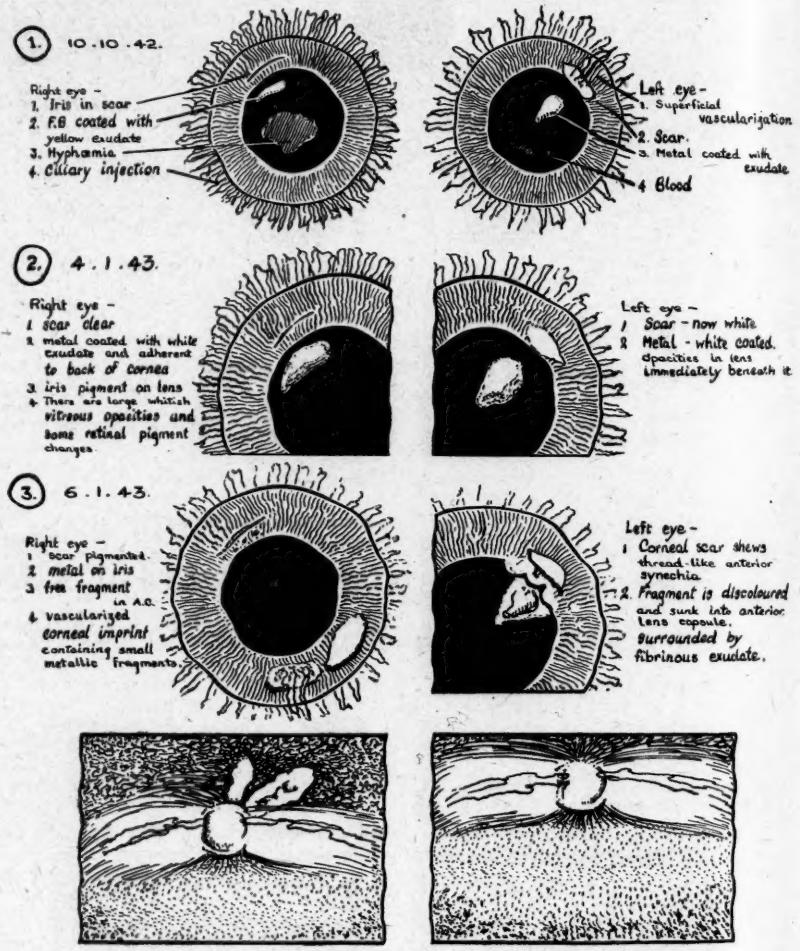
*Left eye -*
*1 a few corneal bullæ*
*2 there are folds in Descemets*
*3. the metal is crumbling, surrounded by lens opacity*
*4. the fundus shows more pigmentation, gross mass posterosuperiorly to disc. Also scattered white patches*

* The protocols on Rabbits Nos. 6, 9, 15, 19, 20, 21 and 24 are devoid of illustrations and appear textually after the protocol on Rabbit No. 23.

## RABBIT Nº 2.

5.10.42.

Under cocaine anaesthesia 1·5 mg. of 98% aluminium was inserted into R. eye by previous technique.
Similarly 0·3 mg. of 98% aluminium was introduced into L. anterior chamber.


1. 10.10.42.
Right eye –
1. Iris in scar
2. F.B coated with yellow exudate
3. Hyphaemia
4. Ciliary injection
Left eye –
1. Superficial vascularization
2. Scar.
3. Metal coated with exudate
4 Blood
2. 4.1.43.
Right eye –
1 scar clear
2 metal coated with white exudate and adherent to back of cornea
3 iris pigment on lens
4 There are large whitish vitreous opacities and some retinal pigment changes
Left eye –
1 Scar – now white
2 Metal – white coated. Opacities in lens immediately beneath it
3. 6.1.43.
Right eye –
1 scar pigmented.
2 metal on iris
3 free fragment in A.C.
4 vascularized corneal imprint containing small metallic fragments.
Left eye –
1 Corneal scar shews thread-like anterior synechia
2. Fragment is discoloured and sunk into anterior lens capsule. Surrounded by fibrinous exudate.
Fundus – patches of choroiditis above disc
Some peripheral pigmentation
Mottled pigmentation of peripheral fundus.

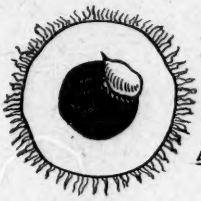
## RABBIT Nº 3.

Cocaine anæsthesia was employed. The R.eye was dislocated outwards and 0·3 mg. group 2. AlCu alloy was inserted without difficulty. The rabbit started when the left incision was made, there was an iris prolapse. The 0·3 mg. group 2. F.B. was fairly easily inserted. The prolapsed iris was snipped off. There was a small vitreous loss.

13.10.42.

Foreign body on anterior lens capsule surrounded by exudate.

RIGHT EYE.



Large iris prolapse covered with fibrin.

The eye appeared injected.

LEFT EYE.

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## RABBIT Nº 4.

17.10.42. Anæsthesia by injection of 0·75 cc. of 1gr per cc. nembutol intravenously into the vein of the L.ear. Cocaine anæsthesia was employed as well. R.eye – a 0·4 mg. fragment of group 9 Al Zn was inserted through a straight keratome incision. L.eye – a 0·5 mg of group 9 Al Zn was inserted through a Taylor knife incision with no difficulty.

9.1.43.

Thread-like anterior synechia. A few metallic flakes embedded in the corneal stroma. The metal fragment has dropped across the anterior chamber. It is seen below, dotted with a few patches of iris pigment.

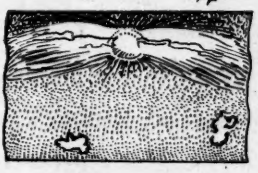
Fundus shows pigmented patches at 7 and 4 o'clock.

RIGHT EYE.

Corneal scar shows a few flakes of metal. Fine anterior synechia. Imprint on the iris. The metallic fragment lies partly coated in the angle of the anterior chamber, at 7 o'clock. The cornea is vascularized superficial to the fragment.

Fundus - peripheral changes below.

(LEFT EYE).



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## RABBIT Nº 5.

25.10.42. Anæsthetised intravenously by injection of nembutal solution gr. 1. 1cc. 0.5 mg. fragments of pure 99.9% aluminium were inserted by the usual technique into the A.C. of each eye.

9.1.43.

Left eye (DIAGRAM). Scar clear. White imprint on the iris at the site of the absorbed metal - Vitreous opacities. - Peripheral fundus changes.

Right eye - Corneal scar is pigmented with fine synechiæ. The metal lies faintly coated, in the angle of the anterior chamber below. There are peripheral choroidoretinal changes.

## RABBIT Nº 7.

8.11.42. Anæsthetised by intravenous injection of 1cc. of grI od 1cc. nembutal. By the usual technique two fragments each of 0.4 mg. aluminium-silicon group 8 were inserted into the anterior chamber of each eye.

1.

Right eye - 9.1.43. Corneal scar is vascularised. FB lies on the ant. lens capsule surrounded by gelatinous material. A line of pigment runs from the everted iris margin to foreign body. There are cortical lens opacities and peripheral fundus changes.

Left eye - Corneal scar is clear. Metal fragment lies on the anterior lens capsule, presenting an iridescent appearance. There is jelly on the front of the metal. Iris margin is everted with pigment on the lens capsule and foreign body. Some opacity of lens. Peripheral mottling of fundus.

2.

Left eye - 16.5.43. The scar is clear. There are posterior synechiæ. The metal seems completely absorbed. There is jelly in the anterior chamber. The lens shows opacities.

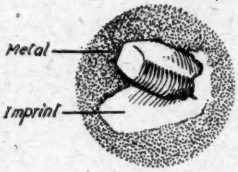
## RABBIT Nº 8.

8.11.42. Anæsthetised by intravenous injection of 1cc. grI od 1cc. nembutal.

Right eye - A Graefe knife scleral puncture was made in the 2 o'clock meridian behind the equator of the globe. A piece of pure aluminium weighing 0·9 mg was inserted with forceps.

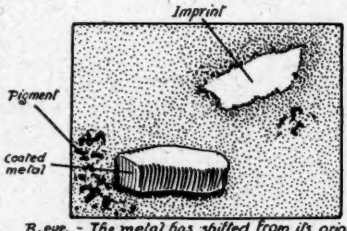
Left eye - A scleral puncture was made in the 10 o'clock meridian behind the equator. 0·9 mg. aluminium was inserted.

1.

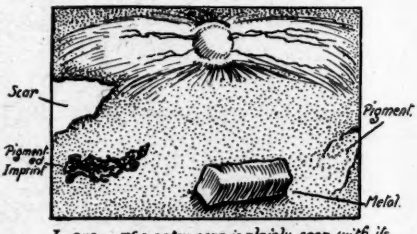



9.1.43. Right eye - Slit-lamp shows a few lens striæ. Fundus examination shows the metallic fragment far forward with an iridescent white coat. - Posterior to the fragment the retinal background shows a pigmented scar thought to be a retinal imprint. Fundus shows pigmented mottling.

2.




R. eye. - The metal has shifted from its original relationship to the pigmented scar, which is now dead white with pigmented edges - The metal, coated with a white material, is lying below. The nearby retinal background shows pigmentation.




L. eye - The entry scar is plainly seen with its pigmented edges. The metal, covered with a white coat, lies some way behind the disc. - It has an iridescent appearance. A pigmented scar lies posterior to the metal, having the appearance of an imprint. There are other pigmented patches near the metal. - Peripheral mottling of the fundus.

## RABBIT Nº11.

27.11.42. The rabbit was anaesthetised by intravenous injection of nembutal, using the usual technique. — A fragment of AlMg group 3 weighing 0·5 mg. was inserted into the anterior chamber of each eye by the previously used method.

Left eye.

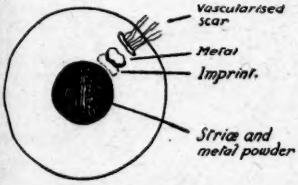
17.1.43. Right eye – Metal fragments in the wound scar. Also an anterior synechia. The main mass of the metal is adherent to the scar posteriorly. It has a yellowish-white coating. There are cortical lens striæ and vacuoles. – Marked peripheral pigmentation in fundus.

Left eye. – The corneal scar is vascularised; there is metallic powder in the scar. The main mass of the metal is adherent to the scar (see diagram above.) The metal is covered with a white and yellow coat. – There are cortical lens opacities and considerable fundus pigmentation.

## RABBIT Nº12.

27.11.42. The animal was anaesthetised by intravenous nembutal into the marginal vein of the ear. Pieces of 0·5 mg. weight AlCu group 2 were inserted into both anterior chambers by the usual technique.

(1)




Right eye. 23.1.43.

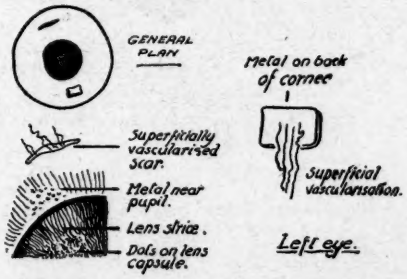
The corneal scar is vascularised. The metal is covered with exudate posteriorly. There is a necrotic area in the iris underneath the metal. There is an adhesion between the iris and the metal. Powdered metal lies on the lens capsule in the pupillary area. – The lens shows striæ. There is considerable fundus mottling.

(2)

Right eye. 30.5.43.

The metal, covered with exudate, lies near the pupillary margin. It has shifted slightly away from the imprint. Dots, streaks and striæ on the lens. Polychromatic lustre on slit-lamp examination.

Fundus changes are more marked and thought to be pathological.




Left eye.

Left eye. Superficial vascularisation of corneal scar. Powdery fragments in scar. – Posterior synechiæ and lens opacities. Some small metallic fragments lie on the anterior surface of the iris. The main metal is adherent to the posterior surface of the cornea. The anterior surface of the metal seems intact; but the cornea over the surface is vascularised.

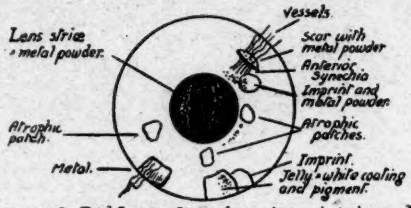
Left eye.

Atrophic area of iris on anterior surface above. This area shows powdery metal. Vascularised iris imprint below the pupil, from which the metal has shifted again laterally. There are posterior synechiæ and lens striæ. Some patches, thought to be pathological, are shown in the fundus.

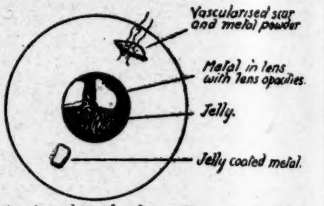
## RABBIT Nº 13.

21. 6. 43. The animal was anaesthetised by 0.75 cc. Nembutal solution. Through posterosuperior corneal incision 4 mg of pure Al (99.9%) was inserted, into the anterior chamber in 1 mg fragments. A similar quantity was inserted into the right eye, but using an anterosuperior incision.

1.

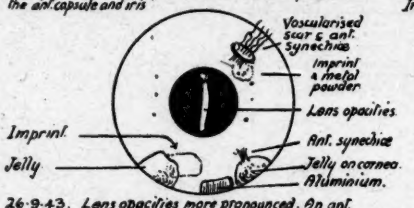



27.6.43 - Right eye. Corneal scar is vascularised and contains some powdered metal. Ant. synechia near the base of which is an iris imprint. Lens striæ and al. powder on the ant. capsule and iris

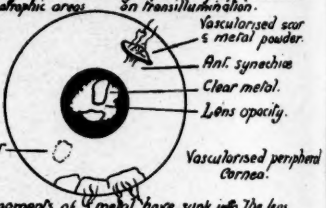



Left eye - Vascularised powdered scar. Two pieces of metal have sunk into the lens, and are surrounded with opacities. Covered with jelly. At lower angle of A.C. lies jelly covered metal. Iris shows atrophic areas. On transillumination.

2.

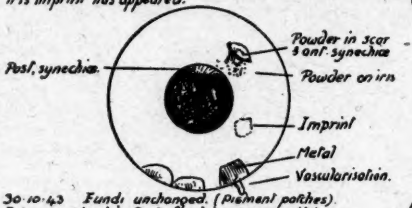



26.9.43. Lens opacities more pronounced. An ant. synechia passes from one of the fragments through the cornea. Jelly on the post. surface + in lower angle of the A.C. + fresh iris imprint has appeared.

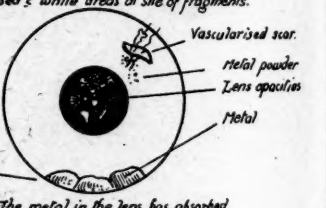



Two fragments of metal have sunk into the lens. Their surface, as far as can be seen is shiny and clean. Imprint on Ant. iris surface at 7 o'clock. Lower cornea is vascularised & white areas of site of fragments.

3

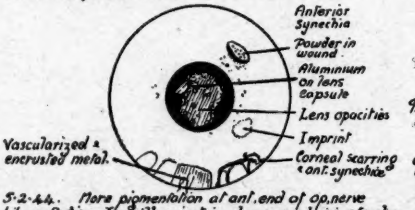



30.10.43 Fundi unchanged. (Pigment patches). Iris more atrophic, Post. synechiæ. Lens opacities more advanced. Metal fragments partially absorbed. New iris imprint at 5 o'clock.



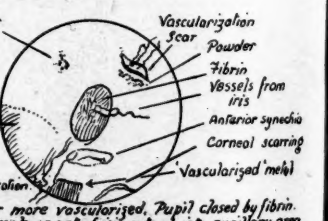

Much of the metal in the lens has absorbed. There is more opacity of the lens.

4.




5.2.44. More pigmentation at ant. end of op. nerve fibres R. disc. Transilluminalion shows much iris atrophy. Above diagram shows still more corneal scarring & anterior synechiæ.

7.5.44. Right eye - No metal left in lower A.C. Some jelly remains. - rather more fundus changes.




Scar more vascularized. Pupil closed by fibrin. New vessels on ant. of iris extend into pupillary area. Large ant synechiæ below pupil. Much corneal scarring. At one point there is an iris bombé.

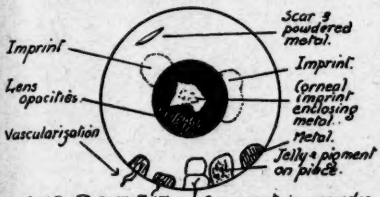
Left eye unchanged but for more vascularisation of cornea.

## RABBIT Nº 14.

21·6·43. Intravenously applied 0·5cc nembutal solution anæsthetic. Through the usual corneal incisions 6 mg. of pure (99·9%) Aluminium was inserted in 1 mg. fragments into each anterior chamber, without particular difficulty.

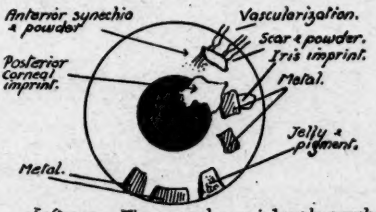
1.

Right fundus — Some speckled pigment. Dark patches in the 6 « 7·3° meridians.



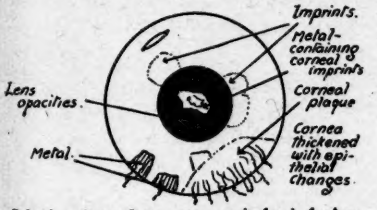

8·8·43 - RIGHT EYE. — Scar contains powdered metal. Multiple iris imprints, and a central corneal imprint which encloses a fragment of the metal. Several of the bits lie in the lower angle of the anterior chamber. They are covered with fine vessels; some are white coated with spots of pigment. — There are many lens opacities. — Fundus shows pigmented patches.

Left fundus — Dark patches in 6 « 4.3° meridians.

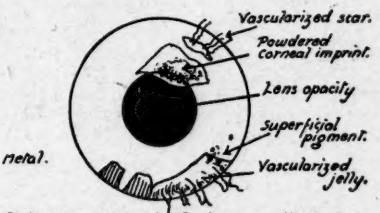



Left eye — The corneal scar is heavily vascularised and incorporates much metal powder. An ant. synechia also contains metal powder. There is a posterior corneal imprint, also an iris imprint. Some of the pieces are bright and others encrusted and coated with jelly and pigment.

2.




5·2·44. — RIGHT EYE — The main fresh feature is a vascularised corneal plaque below. The cornea is thickened with epithelial changes



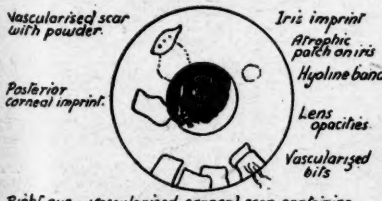

Left eye — The main features are illustrated in the above diagram.

## RABBIT Nº 16.

27·6·43. Anæsthetised by 0·75cc nembutal intravenously. 10 pieces each of 1 mg. 99·9% pure Aluminium were inserted by the usual technique into the right A.C. & into the Left.

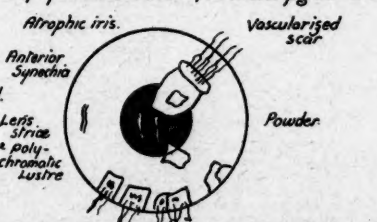
1.

Right fundus showed patches of pigment near the disc in the 6, and 8 o'clock meridians.



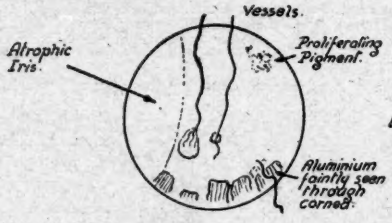

Right eye - Vascularised corneal scar containing powdery metal. - Iris imprint near entry scar. Large posterior corneal imprint. - Ant. border of iris shows atrophic patch. Several metallic fragments in lower angle of A.C. white coated & vascularised - Dots & striæ on lens. - Hyaline band across pupil. Ready transillumination — increased fundus pigment.

Left fundus showed infero-lateral pigmentation.




Left eye — A large mass of jelly, covering a piece of metal lay behind the much vascularised corneal scar. — A second piece of metal was adherent to post. corneal surface. Metallic powder on back of cornea. More jelly post. to metal. Another piece of metal post. cornea, below pupil. — Seven pieces coated with jelly in lower angle of A.C. — Several haemorrhage patches on metal. — Iris much atrophied - Lens lustre & striæ.

RABBIT Nº 16. (Continued).




2.

1.

6.2.44. Right eye — The corneal diameter is 18 mm. and that of the whole eye 22 mm. Much pigment proliferation near corneal margin. There is also an extensive interstitial keratitis with large vessels converging on the centre of the cornea. The iris is atrophic and there is a large anterior synechia. Some of the pieces can be faintly seen through the cornea below. The lens and fundus are not visible.

Left eye — In addition to the appearances formerly noted there were several pigmented plaques on the posterior corneal surface. — More lens opacities - The pieces of metal at the lower angle of the A.C. showed increased powdery fragmentation. - Much jelly and haemorrhage surrounded the fragments, with vascularization of the area.
The left fundus showed much diffuse pigmentation, of probable pathological origin.

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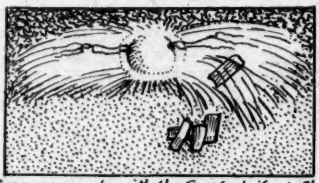
RABBIT Nº 17.

4.7.43. Anaesthetised intravenously by 0·75 nembutal solution.

1.

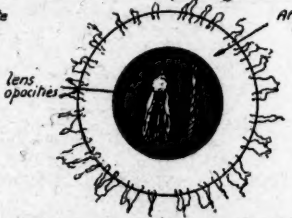


2

Right eye — A scleral puncture was made with the Graefe knife in the antero-superior quadrant of the eye posterior to the equator. 4 fragments of 99·9% pure Aluminium each weighing ·83 mg. were inserted into the vitreous via a puncture which passed through the anterior bundle of opaque nerve fibres. — There was much difficulty in making the pieces stay in position.

Left eye. — 6 identical pieces were inserted into the vitreous through a postero-superior Graefe puncture, a previous puncture through the inferior rectus proving unsuccesful.

2.




6.2.44. Right eye — Cornea showed a band shaped keratitis - vascularisation of corneal margin. The iris pigment of the pupillary margin had proliferated to extend over the anterior capsule of the lens. Iris bombé was present. There was a staring white cataract.

Left eye — Vascularised corneal periphery. Atrophic iris - many lens opacities, more marked in the posterior cortex.
In the vitreous one piece of metal was seen covered with white and attached by fibrous strands to the posterior surface of the lens.
The disc shewed retinitis proliferans anteriorly and posteriorly a necrotic patch.

## RABBIT Nº 18.

4.7.43. Anaesthetised by 0·5cc nembutal solution intravenously.

Right eye - A postero-superior Graefe knife puncture was made. 10 pieces, each weighing 0·83mg of pure Aluminium were inserted with curved forceps into the vitreous. There was some difficulty as the vitreous was apt to herniate.

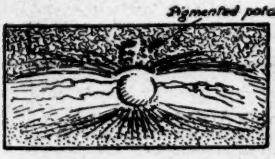
(1)

7.11.43 — Some vascularisation of the deep peripheral stroma of the cornea. Atrophic iris patches. Some small lens opacities.

Ophthalmoscopically the pieces were massed together postero-superiorly in the vitreous. The surface of the metal was iridescent. - some pieces were coated with a white film.

Posterosuperiorly on the retina was a white film. This was partially vascularized but seperate from the entry scar. Fundus otherwise normal except for one or two white patches.

(2)



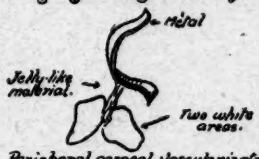

10.2.44. (Above diagrams).

Vascularized corneal periphery, particularly below. - Iris transilluminated generally, particularly at some atrophic patches below. Streak-like lens opacities. Retinal imprint unchanged - metallic fragments perhaps more coated - Pigmented patch above disc.

(3)

7.5.44. Pigment above disc (see above) was more marked - metal + imprints, no change.

Left eye — A postero-superior Graefe puncture was made. An uncut strip of 3 pieces of 99·9% pure Aluminium each weighing 0·83mg. was easily inserted into the vitreous



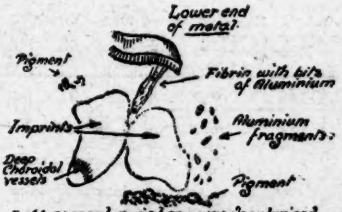

Peripheral corneal vascularization. Iris atrophy. Lens opacities were present.

Fundus — A long curved metal fragment could be seen with a faint white coating.

Posteroinferiorly were two white areas apparently covered with necrotic material.

Near the lower end of the metal was a mass of jelly like material extending between the metal and the retina. - The fundus elsewhere was extensively mottled with white patches.

Posterosuperiorly the entry scar could be seen with pigmentation around. The upper half of the metal was also surrounded with jelly.




Left corneal periphery was vascularized. Iris transilluminated freely. — Several especially atrophic patches.

Retinal imprint near the upper end of metallic fragment. The lower end of fragment had shifted. The metal was coated and a strand of fibrin ran to the two retinal imprints previously noted. Some powdery metal was lying in the strand.

One imprint showed some deep vessels running in the choroid and pigmentation alongside.

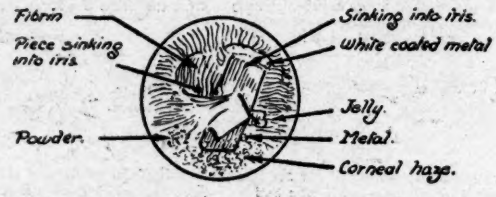
There were some scattered Aluminium fragments near the imprints and some peripheral pigmentation in the fundus below.

7.5.44. Slit lamp appearances unchanged. More pigmentation around retinal imprints.

## RABBIT Nº 22.

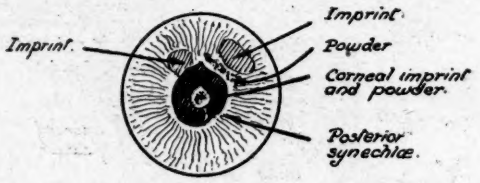
10.10.43. Anaesthetised intravenously by 0.5cc nembutal solution. Through a postero superior corneal puncture 12 mg. of 99.9% pure Aluminium was inserted in two 6 mg. strips into the Right A.C.

1.




7.11.43. Right eye — The two strips, as shewn above, were sinking into the iris. An oblique strip was covered with a fibrinous material save for the lower end which impinged on the cornea. — The cornea was hazy in this area and there was a deposition of gelatinous material near the end of the piece of metal.
The vertical fragment showed sinking into the iris of the upper end. In this region the metal was covered with white deposit.

2.




6.2.44. The two pieces had completely disappeared save for some metal powder on the anterior iris surface. — Two obvious imprints remained on the iris surface. There was a corneal imprint sprinkled with powdery metal.

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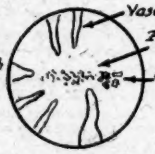
## RABBIT Nº 23.

10.10.43. Anaesthetised intravenously by 0.5cc nembutal. 20 mg. of 99.9% pure Aluminium were inserted into the Right vitreous by a posterior scleral puncture.

1.

Right eye
10.2.44.
Corneal vascularisation with zonular keratitis

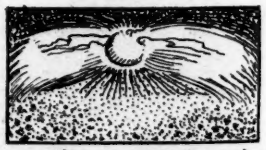



Right eye

Lens opaque with vascularisation of the anterior lens capsule

2.

Right eye
11.5.44.
Cornea ectatic heavily vascularised
Plaque on the anterior surface
A.C. deep + Iris funnel shaped.
White nodule projecting centrally in pupillary area



Fundus mottling was noticed in each eye before the experiment but appeared to have increased in the left eye on examination 11.5.44.

RABBIT No. 6.

8.11.42. An injection of 2 c.c. of gr. 1 ad 1 c.c. nembutal solution was given intravenously into the marginal vein of the ear. The rabbit was rather quiet; but the heart was beating at the start of the experiment. 0.4 mg. aluminium-silicon (group 8) was inserted in the right anterior chamber by the usual technique. The rabbit was found to be dead. It was thought that the death was due to an overdose of anaesthetic. No difficulty appeared in technique etc. during the experiment otherwise.

RABBIT No. 9.

22.11.42. The animal was anaesthetised with 1.75 c.c. nembutal solution intravenously. No difficulty was experienced.

RIGHT EYE. A scleral puncture was made with the Graefe knife accidentally in the 3 o'clock meridian when the animal sneezed suddenly. Afterwards a deliberate puncture was made in the 1.0 o'clock meridian behind the equator. A small bead of vitreous protruded. An attempt was made to insert 0.3 mg. of Group 4 (AlNiCu) alloy. The fragment stuck subconjunctivally. However it was eventually retrieved and thrust with the forceps intrasclerally. It was assumed it was now in the vitreous; but this was difficult to verify ophthalmoscopically as there was some haemorrhage into the eye at the site of the puncture.

LEFT EYE. A scleral puncture was made with the Graefe knife at 10 o'clock meridian behind the equator. A square 0.3 mg. fragment of Group 4 (AlNiCu) was inserted without difficulty and verified in the vitreous ophthalmoscopically.

17.1.43. RIGHT EYE. There were lens opacities. Haemorrhages were seen on the back of the lens and in the vitreous. The metallic fragment had a white coating. The rest of the fundus was normal as far as seen.

LEFT EYE. There were subcortical lens opacities. These shewed polychromatic lustre as seen with the slit-lamp. The metal could be seen covered with a white coating. There were vitreous opacities and bands in the vitreous suggesting retinitis proliferans.

30.5.43. The RIGHT EYE shewed some atrophic iris patches. In addition to the lens opacities the right eye shewed polychromatic lustre in the lens. A collection of blood conld be seen on the back of the lens. There was retinitis proliferans above in the fundus.

The LEFT EYE shewed iridocyclitis with massive keratic precipitates. The iris stroma had atrophied so that vessels shewed through. The pupil was occluded by vascularlsed fibrinous exudate.

27.6.43. The animal became mated.

16.9.43. The animal was killed by the air-embolism method and its eyes enucleated.

RABBIT No. 10.

22.11.42. The animal was easily anaesthetised by 1 c.c. of the nembutal solution intravenously in the marginal vein of the ear. A fragment of Group 4 (AlNiCu) was inserted into each eye without difficulty, the fragment being put into the anterior chamber.

24.1.43. The rabbit had disappeared.

30.5.43. The rabbit was discovered mixed up with other laboratory stock.

RIGHT EYE. There was a pigmented corneal scar with an anterior synechia attached. The lens shewed opacities. The metallic fragment could not be seen. There was gross fundus pigmentation and vitreous opacity.

LEFT EYE. The corneal scar was pigmented. There were anterior synechiae. There were some lens opacities, many vitreous opacities, and much pigmentation. The metal, partially dissolved and very thin, lay below in the anterior chamber.

10.10.43. The rabbit was killed and its eyes enucleated.

RABBIT No. 15.

This was a silver-grey doe weighing 4lbs. The right ear had been bitten badly; the left shewed a smaller bite. The right fundus was rather light with pig-

mented patches at 6 and 8 o'clock meridians. The left fundus showed similar patches at corresponding meridians 4 and 7.

27.6.43. The animal was anaesthetised with 0.5 c.c. nembutal solution intravenously. Two pieces, each 1 mg. in weight, of pure (99.9%) aluminium were inserted into each anterior chamber by the usual technique. There was some haemorrhage into the right anterior chamber. The rabbit recovered and hopped around its cage. Later that day for no apparent cause it was found dead in its cage.

## RABBIT No. 19.

This was a black-and-white buck of approximately old English type.

19.9.43. RIGHT EYE. Five fragments of about 1 mm. square of aluminium foil were inserted into the upper fornix of the conjunctiva. Six hours later the material had worked out of the conjunctival sac leaving the eye normal,

LEFT EYE. Approximately 1 mg. of scrapings from the ribbons were inserted. This seemed to be a mixture of paper, graphite, and aluminium. Six hours later all the material had worked out of the conjunctival sac, leaving the eye normal.

26.9.43. The animal was satisfactorily anaesthetised by 0.75 c.c. of nembutal solution intravenously. A posterosuperior corneal puncture was made in the right eye, and 3 cm. of coiled up platinum wire, weight 15 mg. were inserted into the anterior chamber without difficulty.

The animal was watched for about three weeks during which period the metal seemed to be completely inert. It was then accidentally killed with some other laboratory stock, and the eye was lost.

## RABBIT No. 20.

This was a brown old English buck. Fundi pigmented below disc.

19.9.43. RIGHT EYE. Five pieces of R.A.F. aluminium foil each 1 mm. square were inserted into the upper conjunctival fornix. Six hours later all the material had worked out of the conjunctival sac, leaving the eye normal.

LEFT EYE. 1 mg. of foil scrapings (graphite, paper, and aluminium) were inserted into the upper conjunctival fornix. Six hours later the material had all worked out of the conjunctival sac, leaving the eye normal.

26.9.43. The animal was anaesthetised by 0.5 c.c. of nembutal solution intravenously. The animal was quiet under the anaesthetic; but gave two high pitched reflex squeals.

A posterosuperior corneal puncture was performed in the left eye.

31.10.43. LEFT EYE. The corneal scar was healed. There was a thread-like anterior synechia with a dot-like opacity in the lens at that site.

14.1.44. LEFT EYE. The lens opacity was less marked.

20.1.44. The rabbit was killed and its eyes enucleated.

## *RABBIT No. 21.*

10.10.43. This was a grey doe weighing 3lbs. Fundi were pigmented below the disc and at the lower periphery. The animal was given 0.5 c.c. of nembutal solution and died immediately, apparently from heart failure.

## *RABBIT No. 24.*

This was a black and white doe with rather deeply pigmented fundi.

7.11.43. The animal was anaesthetised with 0.5 c.c. nembutal solution intravenously. The right eye was dislocated and a corneal puncture was performed. The animal was not very deeply anaesthetised and jumped at the critical moment, raising a doubt whether lens or iris were damaged. In the left eye a posterosuperior Graefe puncture was uneventfully performed.

22.11.43. The right eye shewed anterior synechiae. Lens and media were clear. The left eye shewed a small local reaction. There was no vitreous or lens change.

14.2.44. The eyes were quite quiet and settled.

24.2.44. The animal was killed and its eyes enucleated.

## APPENDIX II

*Report on Histological Specimens by*

JOHN O. OLIVER

Owing to circumstances connected with hostilities only 29 out of the 34 eyes with intra-ocular aluminium or aluminium alloy implants came to sectioning. The two eyes of the control rabbit, No. 20, were also sectioned.

Apart from the fact that the cutting of sections from the eyes of rabbits is an especially difficult technical task, and the lens has generally to be removed, there were other difficulties already indicated in Mr. Savin's text. The sections available for study were, therefore, for the most part rather broken up and difficult to orientate.

The general impression on examining the series of histological specimens is that the clinical findings recorded by Mr. Savin are more important than the histological changes indicated in the sections available for study. In some instances there is no possibility of a complete histological diagnosis from the material available.

In drawing conclusions from the specimens available it is important to remember that the individual rabbits were kept alive for some considerable period (upwards of six months) after the initial experiment had been made so that the earlier pathological changes corresponding to the clinical pictures recorded are no longer visible.

### RABBIT 1.

RIGHT EYE. The cornea shows some hyalinisation, but possibly this is merely artefact. The iris (which has been separated from the foreign body mass) shows some thickening and a few small irregular patches of pigmentation. The choroid shows a patch of exudate which is merging with the degenerate retina.

LEFT EYE. The cornea shows a firmly hyalinated zone. The iris shows a few small areas of round celled infiltration and one of these areas contains a foreign body giant cell. The choroid shows some exudate and there is a little degeneration of the retina (less than in the case of the right eye).

### RABBIT 4.

RIGHT EYE. The iris is somewhat atrophied and a little pigmented. The sections do not show the presence of retina.

LEFT EYE. The only lesion appears to be some degeneration of the optic nerve.

### RABBIT 5.

RIGHT EYE. The cornea shows a healed scar but no pigment is visible. The iris shows well marked atrophy and widespread pigmentation. The retina shows some loss of nerve structure from atrophy and there is thinning of the choroid.

LEFT EYE. These sections are not sufficiently complete for diagnosis but there is a well marked atrophy of the retina.

### RABBIT 7.

RIGHT EYE. Very marked retinal atrophy (cystic degeneration in one area).

LEFT EYE. Marked thickening of the cells and some general fibrosis of the iris structure leading to atrophy. Choroido-retinitis well marked with organisation of a thin layer of exudate.

### RABBIT 8.

RIGHT EYE. Retinal atrophy almost complete.

LEFT EYE. Some retinal atrophy.

### RABBIT 9.

LEFT EYE. Complete disorganisation of the lens structure with marked calcification. This calcification was enforced with ciliary body. There is some fibrosis atrophy of the retina.

RABBIT 10.

RIGHT EYE. Some diffuse pigmentation of the iris. The retina shows an area of round celled infiltration and evidence of general atrophy.

LEFT EYE. Very marked retinal disorganisation with gross exudate present.

RABBIT 11.

RIGHT EYE. Some atrophy of the iris. The greater part of the retina shows complete disorganisation of structure (especially marked at the fundus). Peripherally the changes are less and include some degree of cystic degeneration.

LEFT EYE. Very marked retinal exudate with disorganisation of nervous elements.

RABBIT 12.

RIGHT EYE. Sections are not complete enough for diagnosis but the retinal changes present are seen to be comparatively slight.

LEFT EYE. Unsatisfactory for sectioning.

RABBIT 13.

RIGHT EYE. The iris shows some pigmentation and definite degree of atrophy. The retina shows some exudate throughout but this is very patchy and varies from a microscopical quantity at one point to an exudate equal in thickness to the retina itself in other parts.

LEFT EYE. There is complete disorganisation of the eye. A thick exudate with fibrous bands occupies the anterior chamber. The cornea shows some vascular plaques. The lens of the ciliary body is involved in a large mass of cellular exudate admixed with serous material. There is a vascularisation of the choroid and the retina as such has for the most part disappeared.

RABBIT 14.

RIGHT EYE. The iris shows atrophy and a little pigmentation. There is deposit (clearly metallic fragments and exudate) in the anterior chamber. Retinal changes are not very marked but in one zone there is a thin exudate and two small areas of atrophy.

LEFT EYE. Anterior synechiae. Atrophy of iris. The retina is not well shown in the section.

RABBIT 16.

RIGHT EYE. Anterior synechiae corresponding with an area of partial atrophy in the iris which shows some pigmentation. The retina shows a large area of exudate at the fundus.

LEFT EYE. Cornea incomplete (metallic fragments removed), some atrophy of the iris and well marked choroid exudate.

RABBIT 17.

RIGHT EYE. Cornea shows some vascularisation and "wrinkling" from peripheral contraction. The iris shows atrophy and pigmentation. There is a mass of organised exudate posterior to the iris, which in some of the sections is found to be in association with the remains of the lens. Organised inflammatory exudate is present at the fundus. The retina is not seen.

LEFT EYE. Marked vascularisation of peripheral zone of cornea. Iris atrophic from fibrosis and shows a heavy superficial pigmentation. The retina is incomplete but shows an area of retinitis proliferans .

(Note: This case illustrates particularly well the need for examining all the sections available in every instance since no one section could be found giving the complete story.)

RABBIT 18.

*RIGHT EYE. Iris marked atrophy. Retina only minute fragments present.*
LEFT EYE. The iris shows atrophic changes, as also the retina. There is considerable débris in the vitreous cavity.

RABBIT 20.

RIGHT EYE. Some vascularisation of the cornea peripherally.
LEFT EYE. No changes seen with the exception of a healed scar of the cornea.

RABBIT 22.

RIGHT EYE. Shows a healed corneal scar. The only other change observed is some superficial pigmentation of the iris and possibly a minor degree of atrophy.

RABBIT 23.

RIGHT EYE. Sections show the whole eye to have been very much shrunken and distorted. The cornea is vascularised and shows a fibrous plaque on the surface at one point. The iris is completely distorted with numerous adhesions of the proliferated epithelial and vascular process. Some inflammatory exudate is present in the margin of the remains of the lens and an organised exudate is also present in the choroid. The retina shows complete degeneration.

## ANNOTATION

### Tobacco Amblyopia and the Budget

The Chancellor of the Exchequer, in framing this year's Budget, would seem to have adopted the maxim of Mr. Biggs in Mr. Midshipman Easy who said that duty came before decency. It will be interesting to see whether the increased cost of tobacco will have any influence on the number of cases of tobacco amblyopia in Britain. Doubtless substitutes will be found. We have already heard of husbands who have raided the tea caddy to the despair of the prudent housewife. We have known small boys attempt to smoke blotting paper, and both coltsfoot and hay have been recommended. In passing we may ask whether those who use hay will have to obtain a permit from the War Agricultural Department, sub-section, supply of animal food-stuffs?

The non-smoker sees no virtue in tobacco just as alcohol in any form is anathema to those who have taken the pledge. The writer has smoked tobacco ever since his school days, and was not brought up like the "Infant Bond of Joy," Alfred Pardiggle, who "was pledged never, through life, to use tobacco in any form." Like most other things tobacco can be abused, but used in moderation it never seemed to us to do any harm, and it has a distinctly soothing effect. We find it easier to compose an annotation with a pipe in one's mouth than without it. Burton, Anatomy of Melancholy,

Part 2, Section 4, commends its use in moderation, but "as it is commonly abused by most men, who take it as tinkers do ale, 'tis a plague, a mischief, a violent purger of goods, lands, health, hellish, develish and damned, the ruine and overthrow of body and soul." Here is a sentiment to put in our pipes and smoke.

## AMERICAN OPHTHALMOLOGICAL MEETINGS
### June, 1947.

AMERICA surely still remains the land of comfort and of plenty and the home of exuberantly kind and hospitable people. I have just had the happy experience of attending the annual meetings of the American Ophthalmological Society and the American Medical Association, two occasions which deserve putting on record,

The 83rd annual meeting of the A.O.S. was held at The Homestead, Hot Springs, Virginia, from June 5—7. Hot Springs, a delightful resort in the heart of the Virginian hills is an ideal location for such a meeting. It consists of a luxury hotel at a rail terminus in the heart of beautiful country where everything pleases except the taste of the warm sulphur spring water—but there are other things aplenty to taste. The Society takes possession of a section of the hotel and works and plays for three days. It is an exclusive Society, limiting itself approximately to 200 members (there are some 8,000 ophthalmologists in the U.S.A.), embracing all that is good in American ophthalmology; practically everyone attends (three consecutive absences from meetings without valid excuse implies expulsion) and all the world brings his wife. The morning is devoted to scientific papers; the afternoon to tennis, golf, swimming or walking, and the evenings to happiness: sleep comes tardily.

The meeting was under the genial presidentship of John W. Burke of Washington and the scientific papers covered a wide field of interest; the subsequent discussions are usually prepared and are more formal than the spontaneous give-and-take we are accustomed to in England. Two cases were reported by Maynard C. Wheeler (N.Y.) of discolouration of the lids from the use of yellow oxide of mercury sustained over many years. Reports of delayed mustard gas keratitis were presented by Walter S. Atkinson (Watertown)—the condition is apparently rarer (or less frequently spotted) than in England. Two cases of an exceptionally rare tumour of the orbit—granular cell myoblastoma—one simple and one malignant, were reported by John H. Dunnington (N.Y.). The occurrence of papillœdema with cerebral œdema in the manifest form of parathyroid deficiency was described by Donald Lyle (Chicago.)

Daniel Kirby (N.Y.) gave an interesting discussion of his technique of dealing intracapsularly with cataract in eyes in which a fluid vitreous was present; he recommended traction with rotation rather than pressure, gripping the lens capsule at 12 o'clock and if necessary rupturing the zonule by stripping it from its attachment to the lens in this region. Wendell Hughes (N.Y.) described his employment of vitallium implants after enucleation; and the first day's session ended with a contribution by Alan C. Woods (Baltimore) on the deterrent effect of promin and promizole (new drugs) on the course of experimental tuberculosis in immune-allergic rabbits.

The second day's session was opened by two papers on the applications of surgical diathermy—in the treatment of angioma of the retina by Philip M. Lewis (Memphis) and of recurring retinal hæmorrhages by F. Verhoeff (Boston): in the latter case one eye had been blinded by recurrent hæmorrhages followed by retinitis proliferans, the other eye was saved (2 years' history) by obliterating on two occasions the segments of the retina wherein hæmorrhages and retinitis proliferans appeared. Gordon M. Bruce (N.Y.) gave an exceptionally interesting paper demonstarting that certain cases of so-called "primary" hypertension were due to a neoplasm (pheochromocytoma) of the adrenal medulla; in such a condition the retinopathy may be the first clinical symptom and the appropriate surgery is therapeutically effective. This is an important new observation. John P. Macnie (N.Y.) presented the results of treatment of aniseikonia over a 5-10 years' interval, claiming some 50% relief from symptoms. Charles E. G. Shannon (Philadelphia) gave a talk on the thyro-pituitary origin of malignant exophthalmos. James N. Greear (Washington) described his technique of orbital reconstruction with buccal mucosa, and the second day's session ended with a discussion of Mikulicz's disease and syndrome by Parker Heath (Detroit).

The final day's session was occupied by a demonstration of difficulties of diagnosis of retinoblastoma by Arthur J. Bedell (Albany), a discussion on agnostic alexia by Harold H. Joy (Syracuse), on diffuse malignant melanomata of the iris by Shaler Richardson (Jacksonville), and on arachnodactylia by Ralph I. Lloyd (Brooklyn). A. B. Reese (N.Y.) gave an interesting talk on glaucoma, introducing the conception of a "base pressure" and a "peak pressure" (corresponding to a diastolic and systolic pressure, the difference being termed the "functional transitory factor" which becomes nil in absolute glaucoma. He pointed out that it is not sufficient to determine a single intra-ocular pressure, but it is necessary to establish whether it represents the lowest, highest or an intermediary point in the pressure curve: the higher the base

pressure, the greater a drainage load any operation must carry. A preliminary report on an investigation to correlate plasma protein fractions with certain types of lenticular changes was presented by A. D. Ruedemann (Cleveland), and an interesting account of his extensive researches into the difficult and exceedingly complicated question of the standardization of the various types of tonometers by Jonas S. Friedenwald (Baltimore). A final paper on pupillometry closed a most informative and friendly meeting.

On the night of Saturday, June 7 a large party of us travelled from Virginia to Atlantic City to celebrate the centenary of the American Medical Association. Most unhappily our journey was marred by the sudden illness and death on Sunday morning of Dr. E. C. Ellett owing to coronary thrombosis. He was a delightful person who took an active part in the proceedings at Hot Springs, and was one of the most charming and beloved of American ophthalmologists. His widow was with us.

Atlantic City is an amazing city on the eastern sea-board which may be partially visualized by piling Brighton on Margate and both on Blackpool; but its mammoth hotels could accommodate the 15,000 delegates to the meeting of the A.M.A.* Monday (June 9) as well as all the spare moments throughout the week, was occupied by the examinations of the American Board of Ophthalmology. This Board gives a post-graduate certification of fitness to practise as an ophthalmic specialist and is a universal criterion throughout the country for full professional recognition and the higher hospital appointments. The examinations (in which I participated) are of a standard corresponding to our D.O.M.S. and have undoubtedly been a most effective means of raising and maintaining the standard of ophthalmology in the United States.

Tuesday was occupied by the Sixteenth Annual Meeting of the Association for Research in Ophthalmology. This is a very valuable Association encouraging and presenting a forum to junior research ophthalmologists and young scientists without a medical degree. Twelve papers were presented and discussed ranging from the bacteriology of seborrhœic blepharitis and conjunctivitis to the transfer of tracer substances through the blood-aqueous barrier.

The meetings of the Section of Ophthalmology of the A.M.A. took place during the next three days under the delightful and efficient chairmanship of that old English friend of ophthalmologists, Dr. Derrick Vail. His Presidential address was on the prestige of ophthalmology wherein, without pulling any punches, he pointed out

* With a corresponding number of wives together with over 3,000 manufacturers and tradesmen who staged a medical exhibition amazing in its interest and comprehensiveness.

the short-comings of ophthalmologists as a class in the United States and how they failed to attain and maintain the position of members of one of the highest specialities of medicine. It is interesting how international are these sins of omission and commission. I gave an address on the nature of the aqueous humour. Thereafter Dr. Verhoeff gave the centennial address—One Hundred Years in American Ophthalmology. The address was most interesting: the story of progress in American ophthalmology during the last century is indeed a proud one, but, characteristically, Verhoeff, was not backward in pointing out what Americans could have done, and had not. The subsequent scientific papers provided unusually interesting and varied fare. Four cases with keratitis presumably due to the virus of lymphogranuloma venereum were described by H. G. Scheie of Philadelphia. A four-year follow-up of 300 glaucomatous eyes was presented by Peter Kronfeld of Chicago: wide-angled and narrow-angled glaucoma is a favourite basis of classification in America, and the latter type was found to carry the better prognosis with regard to vision after control of the tension. An interesting paper on the surgical significance of the ligament of Lockwood in relation to the surgery of the inferior oblique muscles was presented by Walter H. Fink of Minneapolis. The control of experimental ocular infections both external and internal by streptomycin administered systemically and locally was discussed by John C. Bellows and Chester J. Farmer of Chicago: promising results were obtained after infection of the vitreous by streptococci with local treatment by intra-ocular injection but systemic treatment did not prevent infection; corneal infections by B. pyocyaneus were aborted by local treatment. Unilateral syphilitic optic atrophy was discussed by Walter L. Bruetsch of Indianapolis, and the value of sodium sulphacetamide in ophthalmology by Leo Mayer of St. Louis. Conservative treatment of congenital impatency of the naso-lacrimal duct was advocated by Edwin L. Kendig and Du Pont Guerry of Richmond; and late operation (after 2½ years) in the surgical treatment of congenital cataract by W. C. Owens and W. P. Hughes of Baltimore. Three interesting papers related to the war experiences of some of the younger men—on intra-ocular foreign bodies by G. M. Haik of New Orleans, on military ophthalmology by Don Marshall, and on plastic reconstruction of the lids by S. M. Dupertuis of Pittsburg, in the subsequent discussions of which several of our old friends whom we knew in the European theatre of war participated.

All these, with official receptions and functions, dinners (public and private), and good fellowship abounding, constituted a memorable week indeed.

STEWART DUKE-ELDER.

## BOOK NOTICE

**Clinical Methods of Neuro-Ophthalmologic Examination.** Kestenbaum. $6·75. Greene and Stratton, New York. 1946.

In the introduction to this volume, the author states that its object is "to present a review of the clinical methods of ophthalmologic examination that may be useful in neurologic differential diagnosis." Anatomical data and theoretical experiments are therefore recorded only in so far as they are required for the understanding of the methods described. The book is thus essentially a practical one and is not intended to supersede well-known works on neuro-ophthalmology. Since many ophthalmologists are often not concerned with methods of neurological localisation, and many neurologists are not concerned with ophthalmological methods, the science with which this book deals has, up to date, suffered neglect. Such is no longer the case, and anyone who has read Neuro-Ophthalmologic Examination will have all the information needed to enable him to elicit and interpret the eye signs and symptoms in a case of nervous disease. The author is at pains to point out, however, that such signs and symptoms are only a contribution to the final diagnosis in the same way as are radiological findings, and that the last word must always rest with the neurologist.

As an instance of the thoroughness with which the subject is tackled, it may be mentioned that no fewer than five different methods of non-instrumental perimetry are described, and that in describing instrumental perimetry four common errors of procedure are mentioned, in the hope that by elimination of them the perimetrist will "measure the real visual field, and not the visual acuity, the degree of attention or the size of the palpebral aperture."

Since the author is a well-known authority on his subject, his book contains much that is new, and the result of his own thoughts and investigations. The description of the positions of retinal haemorrhages is a case in point. The disc is regarded as a clock face, and the prefixes A, V and C designate artery, vein and small vessel respectively. A vein crossing the disc at 2 o'clock would be designated V2; the branches into which it breaks up are also numbered in a clockwise direction. V2.2.2. would, therefore, be the right-hand branch of the right-hand primary bifuration of a vein which crossed the disc at 2 o'clock.

The value of the text is enhanced by the inclusion of over 20 tables, which are useful for hasty reference. One of these deals with the 8 different types of chiasmal syndromes, and correlates them with their most common causes; another gives 13 different signs which may aid in localisation of the cause of hemianopia.

Kestenbaum is well known for his work on nystagmus, and as would be expected, his chapter on this difficult subject is full of useful information which is conveniently summarised in tabular form.

Disturbances of ocular movements are also very fully gone into, under the headings of Eye muscle palsy, Gaze movement and Gaze palsy. Various methods are described, but no mention is made of the Hess Screen, possibly because the author is not satisfied with it.

In dealing with the pathology of the optic nerve, the author has much valuble information to give, but he does not mention the absence of papilloedema in purely pontine growths, and the frequent association of a sub-tentorial tumour with the presence of a macular fan.

The characteristics of "neuro-ophthalmologic examination" appear to be:— clarity of expression; simplicity of technique for tests, and the incorporation of much information of practical value which is not obtainable elsewhere. The practical nature of much of the text makes this book a difficult one to review, particularly by armchair reading. One has the feeling all the time that it should be taken into the Clinic, where a far better appraisal of its value could be made by using it as an aid to the investigation of patients.

Dr. Kestenbaum is to be congratulated on having produced a volume of outstanding value.

## CORRESPONDENCE

### CONJUNCTIVITIS IN EXPOSURE TO DIMETHYL-SULPHATE

*To the Editors of* THE BRITISH JOURNAL OF OPHTHALMOLOGY.

DEAR SIRS,—In your latest issue of June (p.373), H. J. Stern describes a case of conjunctivitis due to exposure to vapours of dimethyl-sulphate (abbrev. D.M.S.). He also cites papers of Weber and of different authors, all published early this century. With respect to the rarity of poisoning with D.M.S., it would be of interest to recollect the cases seen at Budapest in 1934. At one of our chemical works, a 1·5lb. glass container filled with D.M.S. was broken by a labourer. One out of the three injured came under care of J. Petres, the other two were seen by the laryngologist G. Boskowitz and myself. (Case record in the Rep. on the 4th General Meeting of Hungarian Physicians 1934). The most severe injuries which ended fatally under symptoms of lung-oedema on the fourth day occurred in the girl who had caused the accident. Thirteen hours

after the injury, tracheotomy had to be performed on account of sudden onset of glottis-oedema; this was followed by a membranous laryngo-tracheo-bronchitis. This massive poisoning resembles that with chlorine, the action of both substances having much in common. With the other patients, there was only some irritation of the respiratory tract. Eye symptoms set in at the very moment of contact with the fumes in all three cases and corresponded to those described by Stern, except that the cornea showed multiple punctate erosions and in the superficial layers round-shaped faint infiltrations which have proved most resistant to therapeutic procedures. A remarkable symptom consisted in corneal hypaesthesia, D.M.S. being a so-called anaestheticum dolorosum. Several weeks passed before the eyes recovered. For first aid we performed lavation with freshly prepared sodium bicarbonate solution. Later, alkaline ointment which had been used against gas-injuries during the first World War, was applied. (Rp. natr. borac. 0,1, natr. bicarb. 0,2, adip Lanae, aqu. dist. aa. 1,0, vasel. flav. 8,0.)

Yours faithfully,

CORNELIUS RAÁB, M.D.

BUDAPEST, V. GEZAU. 3,
*June* 25, 1947

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*To the Editors of* THE BRITISH JOURNAL OF OPHTHALMOLOGY.

DEAR SIRS.—In one of your last issues (June) Mr. H. J. Stern gave an account of eye-injury due to dimethyl-sulphate fumes. May I call your attention to my paper published in the *Amer. Jl. of Ophthal.* (Vol. XX, No. 7, 1937) where the question is fully reviewed. The typical ocular findings are following latency (hydrolysis), corneal lesion varying from mild roughening to extensive erosion, accompanied by photophobia, lacrimation, etc. For treatment I recommend alkaline cream, as possibly the local changes are due to sulphuric acid. On the other hand, methyl alcohol, the other split-product may cause similar erosions on the cornea. Cocaine seems to be contraindicated owing to its undesirable effect on epithelium. Irritating atmosphere should be avoided in after-care. Homatropine is of benefit against sphincter spasm.

I am, Sir,

Yours very sincerely,

STEPHEN DE GRÓSZ, M.D.
*Associate-Professor, Eye-Hospital,*
*University Medical School,*
*Budapest.*

Budapest, Hungary.

## POSITION AND MOVEMENTS OF THE EYE IN OCULOMOTOR PARALYSIS

*To the Editors of* THE BRITISH JOURNAL OF OPHTHALMOLOGY.

DEAR SIRS.—In their note on the position of the eye in third nerve palsy, Mr. Wolff and Surgeon-Commander Heffernan raise several interesting questions. They state quite correctly that the usual description given of the position of the affected eye is "out and somewhat down or simply down and out." The illustrations, however, published in several text books show usually a relative depression of the cornea of the affected eye, which appears to be due to the photograph having been taken with the unaffected eye looking slightly upwards. The text-books are unhelpful in that the descriptions are vague and inexplicit and, an important point, do not state whether the paralysis was complete or not or in what direction the patient was looking when the picture was taken. In one text-book an illustration of bilateral IIIrd paralysis shows both corneae elevated rather than depressed. This obscurity in the text-books arises largely from the habit of copying statements from one book to another without critical examination. I found the following in two text-books:—

"Finally the eye is deviated outward and a little downward because the two muscles that are not paretic, the external rectus and the superior oblique, draw the eyeball in this direction."

"....the eyeball, which is deflected strongly outwards and somewhat down, because the two muscles not paralysed—the external rectus and the superior oblique—draw it in this direction."

It is not likely that in complete IIIrd palsy any apparent downward direction of the affected eye could be produced by the action of the superior oblique and the above statements must be regarded as incorrect.

The second question is:—"What are the movements of the affected eye?"

Berry (1889) explains clearly that the amount of depression possible depends on the position of the eye. If the paralysis is incomplete so that a little power remains in the medial rectus the superior oblique can come into action as a depressor. In such cases a little power might also remain in the inferior rectus. It is interesting to note that in the case described the affected eye could be brought to the midline, presumably owing to relaxation of the left lateral rectus, and yet the patient was unable to turn the cornea downwards. One would be glad to have the authors' comment on this feature of their case.

The late W. G. Sym used to pose a test question to examination candidates:—"How does the eye move in oculomotor paralysis when the patient is asked to look down?" The correct answer was "Nasal rotation of the cornea only". I have myself never seen depression of the cornea in complete IIIrd paralysis.

The third interesting point is the absence of any affection of the optic nerve in the case recorded. It is noteworthy that in cases of a blow to the temple in which the optic nerve is damaged the motility of the eye is unimpaired and where a traumatic paralysis occurs the optic nerve escapes.

Yours faithfully,

H. M. TRAQUAIR.

EDINBURGH.
*July 8, 1947.*

## COLOUR VISION IN THE CONSULTING ROOM

*To the Editors of* THE BRITISH JOURNAL OF OPHTHALMOLOGY.

DEAR SIRS.—I was pleased to see the letter from John Grieve regarding my article on colour vision, and am glad to give the explanation he requires.

The article, "Colour Vision in the Consulting Room," was a very brief résumé of some work I had done which was not published in full owing to the paper shortage, and naturally any detailed descriptions were omitted.

I made no claim that the figure of 5·5 per cent. for the gross incidence of colour defectives was anything other than the actual percentage of the subjects I had examined. These men were not chosen at random from the male population and any generalisation would have been misleading.

I consider it would have been a waste of space to describe the correct technique for using the Ishihara plates in an ophthalmological journal, and likewise considered a detailed description of the construction of the various lanterns, some of which were made from black-out shades and coffee tins, entirely irrelevant: the number and size of the apertures and the use of a rheostat appeared to be the only data necessary. The filters used approximated to those recommended by the International Committee for Aerial Navigation.

No laboratory methods could be applied to my tests, hence the title I used, and variations in colour temperature were ignored.

I hope that the résumé had made it clear that single and multi-light lanterns functioned differently, the first emphasising successive contrast, the second simultaneous contrast, and/or successive, if, for the sake of argument, one supposes that macular fixation allows only one object to be seen at a time, a point which it is not my intention to discuss.

Yours truly,

FRANK R. NEUBERT.

HAUTERIVE,
THE QUEEN'S ROAD,
GUERNSEY.
*July 12, 1947.*

## VISUAL DEFECTS IN ARMY RECRUITS

*To the Editors of* THE BRITISH JOURNAL OF OPHTHALMOLOGY.

DEAR SIRS,—R.A.M.C. Ophthalmologists have recently completed a survey of visual defects amongst the recruit intake in the United Kingdom.

Some figures were obtained relative to men whose uncorrected vision in one eye was 6/18 and below.

During the survey of a recruit population of 13,705, some 1,099 men were found to have monocular vision of 6/18 and below.

ANALYSIS.

| Cause. | Percentage of Partial Amblyopes. | Percentage Recruit Intake. | |
|---|---|---|---|
| High Refractive Error | 39.2% | 3.1% | |
| Strabismus ... ... | 32.7% | 2·6% | |
| Trauma ... ... | 10.7% | 0.9% | |
| Inflammation... ... | 6.2% | 0.5% | |
| Degeneration... ... | 6.1% | 0.5% | = 8% |
| Congenital Defect ... | 1·6% | 0.1% | |
| *Cause Undetermined* | 3.5% | 0.3% | |

Comparable figures were published in the Archives of Ophthalmology (1944, Vol. XXXI, May, p. 399-402) by Theodore, Johnson Mills and Bonser. They examined 10,532 men for visual defect out of a recruit population of 190,012.

ANALYSIS.

| Cause. | Percentage of Partial Amblyopes. | Percentage Recruit Intake. | |
|---|---|---|---|
| High Refractive Error | 24.9% | 1.4% | |
| Strabismus ... ... | 24.2% | 1.3% | |
| Trauma ... ... | 18.1% | 1.0% | |
| Inflammation... ... | 1.9% | 0.1% | |
| Degeneration... ... | 1.0% | 0.06% | = 5.5% |
| Congenital Defect ... | 2.3% | 0.13% | |
| *Cause Undetermined* | 27.6% | 1.53% | |

Periodic "sample" surveys have been taken by the Ministry of Labour and National Service Candidates rejected for visual defects:—

| | | | | | |
|---|---|---|---|---|---|
| 1939—1941 | 1.08% | of all candidates | rejected | for | visual defect. |
| 1942 | 1.13% | „ | „ | „ | „ |
| 1943—1944 | 0.7% | „ | „ | „ | „ |

The Ministry of Education pamphlets give estimates of 0.02-0.03% for blind children, and 0.1% for partially sighted children for all registered pupils. Such children will ultimately constitute a large group amongst the National Service Board rejects.

The present Visual Standard applied in the Army may be summarized as follows :—

| | |
|---|---|
| *Standard One* | Unaided vision to 6/6 in the one eye and 6/9 in the other. |
| *Standard Two* | Unaided vision is either 6/12 in both eyes or Right eye 6/6 and Left eye 6/36. |
| *Standard Three* | Vision correctable to Standard Two. |
| *Standard Four* | Vision correctable to 6/12 in the one eye, and 6/36 in the other. Right or Left eye can be the "Master" eye. |
| *Standard Five* | Vision correctable to 6/24 in both eyes. |
| *Standard Six* | Vision correctable to 6/12 in the one eye and in the other not less than 6/60. There are limitations to the degrees of myopia or hypermetropia permissable. |
| *Standard Seven* | Rejects or especially retained low category serving soldiers. |

A recent analysis of the Ministry of Labour showed that the intake figures for men in Visual Standard Six were 0.6% of the total.

The British figures of 8% and American 5.5% would appear to cover most of the defects from Standard Two-Standard Six.

It is felt that the results of the investigation may be of interest to school medical authorities, industrial ophthalmologists and the future National Health Ophthalmic services.

Yours faithfully,

G. C. DANSEY-BROWNING,
*Lieut.-Colonel, R.A.M.C.*
*Adviser in Ophthalmology.*

Q. A. MILITARY HOSPITAL,
MILLBANK, S.W.1.
*June 6, 1947.*

## NOTES

**National Society for the Prevention of Blindness**

CONRAD BERENS, M.D., of New York City, was elected vice-president of the National Society for the Prevention of Blindness at the semi-annual meeting of the Board of Directors, on June 6, 1947. Eugene M. Geddes, also of New York, was elected treasurer, succeeding George C. Clark.

Re-elected were the Society's president, Mason H. Bigelow, of New York; two other vice-presidents, Preston S. Millar, of New York, and Russell Tyson, of Chicago; and, as secretary, Regina E. Schneider, of New York.

**Sociedad de Oftalmologia del Litoral**

The Officers of the Sociedad de Oftalmologia del Litoral for the session 1947-1948 are as follows: *President:* Dr. Enrique V. Bertotto. *Vice-President:* Dr. Arturo Reca. *Secretary:* Dr. Juan Manual Vila Ortiz. *Treasurer:* Dr. Roberto Giqueaux. *Council:* Drs.: Luis A. Gallo, Fernando Miquelarena, Benito Bianco y Cayetano D'Eramo. The new address of the Society is (Italia 663, local del Círculo Médico, Rosario, Argentina.)

* * * *

**The Ophthalmological Society of New Zealand (B.M.A.)**

IT is a matter for congratulation to all concerned that, in February last year, at the Biennial meeting of the B.M.A. held in Auckland, New Zealand, the Ophthalmological Society of New Zealand was formally constituted.

The first annual conference was held in Auckland in February, 1947, the second will be held in Dunedin from February 3-6, 1948. The Patron of the Society is Sir H. Lindo Ferguson, C.M.G., the sole remaining original member of the Ophthalmological Society of the United Kingdom. The following officers were elected in 1946. *President:*—W. A. Fairclough; *Vice-President:*—G. W. Harty; *Executive:*—H. Coverdale, E. L. Marchant, R. P. Wilson; *Hon. Secretary Treasurer:*—W. J. Hope Robertson; *Hon. Secretary of Conference:*—C. A. Pittar. The same officers with the addition of Dr. L. A. Lewis as an extra Vice-President will serve for the current year.

The first conference was held at the Auckland Hospital: the programme was varied and interesting.

We extend a most cordial welcome to the New Zealand Ophthalmological Society and hope that it may be possible in future years for us to publish a brief survey of each annual conference.

* * * *

**American Ophthalmological Society: Officers**

THE officers elected at the recent annual meeting of the American Ophthalmological Society are as follows:—

*President:*—Dr. Henry C. Haden; *Vice-President:*—Dr. Bernard Samuels; *Editor:*—Dr. Wilfred E. Fry; *Secretary-Treasurer:*—Dr. Walter S. Atkinson.

* * * *

**Courses in Illuminating Engineering.**

IN response to the demand for courses in Illuminating Engineering, two such courses have been arranged to take place in London during the period September, 1947 to May, 1948, one at the Northampton Polytechnic on Wednesday afternoons and evenings, the other at the Borough Polytechnic on Thursday afternoons and evenings.

The courses will prepare candidates for the City and Guilds of London Institute intermediate examination in Illuminating Engineering.

A course has also been arranged at the Central Technical College, Birmingham, to commence in September this year and other courses are in prospect at Cardiff, Leeds, Liverpool and Manchester, further details of which will be available from the Illuminating Engineering Society, 32, Victoria Street, London, S.W.1, in due course.

* * * *

AS Foreign Guest of Honor at the Centennial Meeting of the American Medical Association in June, 1947, at Atlantic City, Sir Stewart Duke-Elder was made an Honorary Fellow and presented with the Ophthalmic Research Medal of the Association.

* * * *

**Transactions of the Ophthalmological Society of the United Kingdom.**

BACK numbers of the Transactions may be obtained through Headley Brothers, The Invicta Press, Ashford, Kent, at the charge of £1 to members of the Society and £2 to non-members.

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**Corrigenda**

UNFORTUNATELY authors' corrections of the paper by Professor E. Th. Levkoieva were not received till June 15. The following corrections should be noted: p. 339, thirteen lines from the bottom of the page should read "in 1942, among 364 enucleated traumatised eyes." Two lines lower down "In 412" eyes enucleated should read "In 42" eyes. Page 342—end of first paragraph "H. K. Müller, in 1945 in his book" should read, "H. K. Müller, in 1945, in his paper printed in the book" (Editor, R. Thiel). Page 345—end of first paragraph should read "The characteristic triangle . . . was seen by us in the majority of all examined cases of Kuhnt's operation in small perforating wounds when regeneration is obvious." Page 348—3 lines below illustration for "diascleral" read "episcleral," Page 353—Last paragraph but two (Preobrajenskaja, M.N.) for G.N. Page 358—Fig. 9, legend should read "Interstitial Argyrophil substance stained by Snezarev's method."